Reading Research Quarterly

Review of Research

Bridging Reading Comprehension and Conceptual Change in Science Education: The Promise of Refutation Text

Gale M. Sinatra
University of Southern California, USA

Suzanne H. Broughton
Utah State University, USA

Consulting Editors:
Irene-Anne N. Diakidoy, *University of Cyprus, Nicosia*
Panayiota Kendeou, *Neapolis University Pafos, Cyprus*
Paul van den Broek, *University of Minnesota, Twin Cities, and Leiden University, The Netherlands*

ABSTRACT

The use of texts in science classrooms has waned significantly over the past two decades. However, recently, researchers have shown renewed interest in the use of refutation texts as a tool for promoting conceptual change and science learning. In this article, we examine the intersection of conceptual change and reading comprehension research in science education. We begin by explaining how researchers in conceptual change have turned their interests toward text comprehension. We then examine models of reading comprehension that contribute to our understanding of how text can promote science learning in general and conceptual change in particular. Next, we examine recent empirical research concerning the effect of refutation text in promoting conceptual change in science. We close with suggestions for future research that seeks to integrate these two areas for the advancement of both scientific literacy and literacy skill development.

As evidenced by the recent publication of the first *International Handbook of Conceptual Change* (Vosniadou, 2008), it has been well established that learning in science is a matter of changing one's preconceived notions about the natural world. There has also been a long-standing and well-established link between learning in all domains and text comprehension (Alvermann, 2001; Diakidoy, Mouskounti, & Ioannides, 2011). Yet in the area of science learning, expository texts have faired poorly as vehicles for promoting comprehension, learning, and conceptual change. Text formats designed to promote a change in students' thinking have shown promise for bridging the gap between the necessary elements to promote conceptual change, comprehension, and learning from science text (Tippett, 2010). There is every reason to believe that these formats can be applied successfully in domains other than science, but the research to date has been overwhelmingly focused in the domain of science.

In this article, we examine the intersection of conceptual change and reading comprehension research in science learning. The rationale for this review at this time is threefold. First, there has been a resurgence of interest in text as a medium for prompting the conceptual change process. Second, the benefits of text as a catalyst for promoting conceptual change are becoming clear, while at the same time, the use of text in the science classroom has recently diminished. We hope to call attention to this contradiction. Third, we hope to inspire researchers from a variety of fields to contribute to the growing intersection of the fields of text comprehension and conceptual change research.

We begin by discussing the role of text in the science classroom. Next, we introduce conceptual change and explain how researchers in conceptual change have turned their interests toward text comprehension. We then examine models of reading comprehension that contribute to our understanding of how text can promote science learning in general and conceptual change in particular. Next, we examine recent empirical research concerning the effect of refutation text in promoting conceptual change. Refutation texts are written to invite readers to make a direct comparison between their prior knowledge and the text information. We close with suggestions for future research that seeks to integrate these two areas for the advancement of both scientific literacy and literacy skill development.

Text in the Science Classroom

Interest in the role of text in science teaching and learning has significantly waned in recent years (Yore, Bisanz, & Hand, 2003). The decline of text as the cornerstone of science instruction can arguably be traced to the increased emphasis since the early 1980s on the inquiry-based learning approach to teaching and learning science (Yore et al., 2003). National reform movements (American Association for the Advancement of Science, 1993) have heralded inquiry as a more active and engaging form of science instruction, one that promotes greater content knowledge and helps students identify with scientists and their work. Thus, inquiry is attractive for both the development of science understanding and the potential development of future scientists. With the focus of most science educators aimed toward engaging students in *doing* science (Settlage & Southerland, 2007), less and less classroom time has been spent on reading about scientific content or process (Center on Education Policy, 2008).

There is reason to suggest that text is not just marginalized in science due to the restructuring of science curriculum; rather, it may be that the use of science instructional texts has been deliberately deemphasized. Researchers have shown that comprehending expository texts, especially science texts, can be quite challenging for learners (Chambliss, 2002; Mason & Gava, 2007; Williams, Stafford, Lauer, Hall, & Simonne, 2009). Hence, it could reasonably be argued that reading about science content, particularly in textbooks, has many drawbacks (Broughton & Sinatra, 2010; Goldman & Bisanz, 2002; van den Broek, 2010). A large body of research has documented the fact that expository textbook passages are difficult to comprehend (e.g., see McKeown, Beck, Sinatra, & Loxterman, 1992). Coherence breaks (Beck, McKeown, Sinatra, & Loxterman, 1991), unrealistic assumptions about readers' background knowledge (McKeown et al., 1992; O'Reilly & McNamara, 2007), unfamiliar or highly technical vocabulary, high density of new concepts (Mikkilia-Erdmann, 2002), and a high inference demand (Beck et al., 1991) are just a few of the empirically documented challenges of content domain text comprehension.

With the demands of the Elementary and Secondary Education Act (ESEA), reading comprehension instruction has been front and center in the minds of educators, school district personnel, and educational researchers. Some have argued that time spent on science in the classroom has significantly declined in direct relation to the renewed emphasis on reading comprehension (e.g., see McMurrer Report, 2008). In other words, educators are compelled to spend their time preparing students for mandated reading tests, and science therefore gets short shrift. The Center on Education Policy (2008) reported that among those districts that claimed to have increased instructional time for the language arts and mathematics in elementary classrooms in order to accommodate the requirements of ESEA, over half (53%) reported they had decreased instructional time for science by 75 minutes or more per week.

We argue that having to choose between reading comprehension and science content instruction is a false choice because both are essential components of a literate society. Instead, we support the integration of reading comprehension and science instruction for the betterment of both. Indeed, the relationship between text comprehension and science learning takes on an even more important role when considering conceptual change learning. Learners must comprehend the scientific model or explanation presented in a text before any restructuring of their previously held misconceptions can occur (Rukavina & Daneman, 1996).

Conceptual Change in the Science Classroom

The reader might wonder, How does conceptual change relate to learning from text? Conceptual change is the process of restructuring knowledge (e.g., see Dole & Sinatra, 1998; Murphy & Mason, 2006). There are multiple theoretical approaches to the study of such learning situations; however, many researchers agree that learners come to the science classroom with ideas formed through their everyday experiences that conflict with science content. A classic example from the cognitive developmental perspective comes from very young students learning about the shape of the earth (Vosniadou & Brewer, 1992, 1994). A spherical notion of the earth is a difficult one for young learners to grasp for the following reasons:

- Their everyday experiences belie this notion.
- Their experiences with a globe or ball suggest that objects on the surface of a sphere would quickly fall off when the sphere shifts position or rotates.
- There is little opportunity to experience the earth's actual shape firsthand, which led early explorers to assume the earth was flat.
- The idea of the earth's shape is deeply connected to many other concepts (e.g., seasonal change, gravity, the day/night cycle).

Thus, concepts such as the shape of the earth are deeply embedded in what some have called a conceptual ecology of the learners' background knowledge (Posner, Strike, Hewson, & Gertzog, 1982). Posner and colleagues described conceptual ecology as a set of epistemological commitments related to the nature of knowing.

Research in conceptual change has a long history dating back to Piaget's distinction between assimilation and accommodation (for a review of the history of conceptual change research, see Vosniadou, 2008) and burgeoned during the days of the cognitive revolution. Researchers at this time focused on describing conceptual knowledge development, identifying misconceptions, and designing instructional materials to support change (Dole & Sinatra, 1998; Sinatra & Mason, 2008).

Today there are multiple theoretical perspectives on the form and nature of the conceptual change process. Researchers interested in a full review of all major theoretical perspectives should turn to the *International Handbook of Research on Conceptual Change* (Vosniadou, 2008). For our purposes, we review several perspectives to give the reader a foothold on critical issues in the field.

Current researchers in conceptual change come from a wide range of theoretical perspectives, disciplines, and philosophical orientations, leading to different characterizations of the change process. First, researchers differ in the degree to which they consider conceptual change to be driven primarily by the unfolding of cognitive developmental potential or to be prompted by experience and instruction. A second major theoretical distinction can be seen between researchers who view learners' ideas as demonstrating a conceptually coherent, although nonscientific, sense-making construction of their world, and those who view learners' ideas as coalescing from a starting point of fragmented and incoherent building blocks of fundamental bits of knowledge. A third distinction is the degree to which conceptual change is a spontaneous, bottom-up process or a deliberative, intentional, reflective process. Finally, perspectives diverge on the degree to which conceptual change is a rational, individual, cognitive process or a sociocultural phenomenon embedded within and unique to a particular time, place, and context. While it is impossible to capture the richness and diversity of perspectives in the field of conceptual change research in a few broad brushstrokes, most researchers would be able to locate their work somewhere on each of these continua—developmentally versus instructionally driven, coherent conceptions versus fragmented knowledge, spontaneous versus intentional, and individually versus socially constructed—with many researchers holding intermediate views on one or more of these theoretical stances. We discuss these continua in turn.

Conceptual Change as a Cognitive Developmental or Instructionally Driven Process

Cognitive developmental theorists have tried to capture the nature of changes in young children's thinking over the course of their development since the time of Piaget. A modern perspective on the qualitative changes that occur in children's conceptual knowledge is well captured by Carey (2009), who described the process of conceptual change as creating "new representational resources that are qualitatively different from the representations they are built from" (p. 18). These new representations may come about through an ontological category shift or the reassignment of a concept to a new and qualitatively different category (Carey, 1991; Chi, 1992), or it may also describe the process of combining or distinguishing concepts, such as when children can differentiate between heat and temperature (Smith, Carey, & Wisner, 1985).

Carey (1991) described these new representations as incommensurate with prior ones, meaning that the prior representations are no longer present in the same form in the new representations. According to such a view, conceptual change is a transformative developmental process brought about by classical developmental mechanisms, such as maturational unfolding of potential through interaction with objects and others in the environment. It should be noted that this perspective often likens these revolutionary changes in children's thinking to the revolutions in scientific thinking that have occurred historically.

In contrast, others have described conceptual change as instructionally induced (Inagaki & Hatano, 2008; Vosniadou & Mason, 2011). Conceptual change that occurs over the course of development comes about in large part without exposure to intentional, formal instruction. However, researchers interested in instructionally induced conceptual change described changes in knowledge that are primarily ignited by exposure to formal instruction that contradicts the students' preexisting conceptual knowledge. A classic example, described earlier, is when young children who hold a flat earth concept are exposed to instruction about the spherical shape of the earth. In this circumstance, the process of conceptual change is one of overcoming naïve conceptions or misconceptions, often formed through the development of conceptual knowledge as described in the developmental view. In contrast to developmental conceptual change, which occurs "naturally" without the requirement of formal instruction (although formal instruction could play a role), the process of overcoming prior conceptions through instruction is a difficult one that learners often actively resist.

There are many ideas in science that, like the shape of the earth, contradict students' background knowledge and experiences. According to the instructionally induced perspective, conceptual change is not easy to achieve. In part, it is difficult because of the interconnectedness of students' conceptual knowledge; there are, let's say, many moving parts involved in knowledge restructuring. It is also difficult because the new ideas often seem incredible (a student might wonder if there are people standing upside down on the other side of the globe, and if so, why they don't fall off). The ideas are complex and challenging to understand (Chinn & Samarapungavan, 2001). For example, the notion that a solid table is actually made up of invisible moving parts called molecules may be difficult for students to believe. Moreover, students may resist new ideas that they view as in conflict with ones they hold dear. Recent perspectives on "The Warming Trend" in conceptual change acknowledge that *hot* constructs such as emotions and motives play a significant role in whether students will resist or adopt new ideas (Sinatra, 2005, p. 107). Topics such as evolution (Sinatra, Brem, & Evans, 2008; Sinatra, Southerland, McConaughy, & Demastes, 2003), climate change (Sinatra, Kardash, Taasoobshirazi, & Lombardi, 2010), and even the ongoing debate surrounding Pluto's demotion to dwarf status (Broughton, Sinatra, & Nussbaum, 2011) can be difficult for learners as they spark strong emotions, create threats to personal identity, or foster resistance based on motivations to retain existing ideas (for a review of the role of motivational constructs in conceptual change research, see Sinatra & Mason, 2008). Because the process of text comprehension is fundamentally one of making connections between background knowledge and text content, it is clear why text that contradicts students' background knowledge may be challenging to comprehend on one hand but may also hold the power to promote conceptual change on the other.

As with all dichotomies, both the cognitive developmental and instructionally induced views on conceptual change have much merit, and both perspectives have considerable empirical support. Each view describes different but compatible perspectives about the nature of change. That is, core mental representations likely undergo radical restructuring over the course of a child's development, and instruction likely brings about changes in that child's acquired conceptual content knowledge.

Conceptual Coherence Versus Fragmentation

Conceptual change theorists differ in the degree to which they view young children's naïve, nonscientific knowledge structures as having explanatory coherence for the learner. Developmentalists working from the theory-theory approach (Carey, 1992) or the framework theory view (Vosniadou, Vamvakoussi, & Skopeliti, 2008) argue that young children's experiences are organized into fairly coherent structures that serve to provide explanations of their world. It is these theories or frameworks that later undergo significant restructuring (Vosniadou et al., 2008). As an example, young children have a well-structured conception of what it means to be alive, but their concepts are often not scientifically correct because they may fail to categorize plants and trees as animate (Carey, 1985). However, young children are able to think and reason with their naïve, nonscientific concepts and make predictions (many of which would not be scientifically accurate). For some, their ideas therefore warrant the descriptor *theory*. Vosniadou and Mason (2011) explained, "They are called theories to highlight the fact that they represent a relatively coherent body of knowledge characterized by a distinct ontology and causality that can give rise to prediction and explanation" (p. 224).

In contrast to this "coherence perspective," diSessa (2008) and his colleagues described the novice knowledge base as a collection of elemental parts known as "phenomenological primitives" or "p-prims," which stem from learners' encounters with the physical world (p. 40). Rather than a process of *conceptual* change, this view describes change as a result of the amalgamation of preconceptual "knowledge pieces" into larger, more complex knowledge structures. According to this perspective, these structures, unlike naïve concepts, must be referenced to scientific concepts, such as the laws of physics, for justification.

This difference in theoretical orientation has been ongoing in the field for some time. However, as with the other dichotomous perspectives characterized above, there is likely merit to both perspectives. It is possible that theorists in these two camps are describing phenomena at different "grain sizes" (for an extensive discussion of the grain size issue, see diSessa, 2008). P-prims are considered to be "intuitive ideas at a sub-conceptual grain size" (diSessa, 2008, p. 38), whereas coherence theorists describe systems of knowledge that are structurally at a grain size more akin to a schema. Individuals likely have both fragmented knowledge and some more or less coherent knowledge structures from which they can think and reason. These two forms of knowledge probably both exist, with children and adults possessing some fragmented and some coherent knowledge on different topics.

Spontaneous Versus Intentional Conceptual Change

Conceptual change can be characterized as either occurring spontaneously or as driven by the intentions of the learner (Sinatra & Pintrich, 2003b). Spontaneous change describes the situation where learners do not take conscious control of their knowledge restructuring but rather change occurs unintentionally. The construction of a synthetic model (Vosniadou & Brewer, 1994) is an example of non-intentional change. Young students learning about the spherical shape of the earth may conclude the earth is round like a pancake. Thus, according to this perspective, learners sometimes create mental models that are an amalgamation of the new and the existing conceptions. It is unlikely that learners intend to construct a pancake model of the earth; rather, this mental model is constructed spontaneously as a result of an incorporation of new information into existing knowledge structures.

Spontaneous change is not just a result of instruction, however; it can also be developmentally or experientially driven. Inagaki and Hatano (2008) described spontaneous conceptual change as naturally occurring change "that results from children's increasing experience in their physical and sociocultural environment" (p. 242). The label *spontaneous* should not be taken to mean that change necessarily occurs quickly. It may appear to happen suddenly, but just as a pile of rocks can "spontaneously" restructure in organization with the addition of one rock, spontaneous change can be the result of years of accumulated experiences.

In contrast, Sinatra and Pintrich (2003a) described intentional conceptual change as a form of change under some degree of learner control. Specifically, they define this type of change as the "goal-directed and conscious initiation and regulation of cognitive, metacognitive, and motivational processes to bring about a change in knowledge" (p. 6). In this view, intentional conceptual change (in contrast to spontaneously occurring change) is a self-regulated, consciously directed process in which learners are motivated to resolve discrepancies between their knowledge and the new information and take deliberate steps to do so (for an extensive discussion of this process, see Sinatra & Taasoobshirazi, 2011).

It is important to note that many theorists believe that this dichotomy does not describe a theoretical difference among conceptual change approaches but rather describes two forms of conceptual change that are theoretically compatible (Inagaki & Hatano, 2008; Sinatra & Pintrich, 2003b). Differences do exist among researchers in terms of their judgments as to the frequency of these forms of change. Some researchers exclusively describe spontaneous change (Carey, 1985), others claim that intentional conceptual change is an important, if rare, phenomenon (Sinatra & Pintrich, 2003a). It is possible that there are those who view intentional change as more frequent once the significant developmental changes of early childhood have occurred and instruction begins. Although we are not aware of anyone who has explicitly made such a claim, it could be theoretically defensible.

The importance of the distinction between these two types of conceptual change will become relevant once we explore different models of text processing. To presage that discussion, some text processing models allow for a greater role of readers' goals and intentions in the comprehension process than others.

Individually Versus Socially Constructed Conceptual Change

Finally, a distinction may be drawn among theorists regarding the degree to which they view conceptual change as primarily a cognitive process of change in an individual's mental representation of knowledge, or a socially situated process where changes occur in the discourses and practices of a community of learners (for an excellent overview of these contrasting positions, see Mason, 2007).

As described by Mason (2007), the traditional conceptual change research from both the early cognitive-developmental perspectives (Carey, 1985) and that of science education (Posner et al., 1982) tended to focus more on the individual cognitive construction and reconstruction of mental representations of content knowledge. Theorists from these perspectives attempt to capture increasingly sophisticated knowledge representations as they develop through maturation and instruction. These representations are described variously as schemas (Rummelhart, 1980), mental models (Vosniadou & Brewer, 1992), ontological categories (Chi, 1992), or domain-specific theories (Wellman & Gelman, 1998). For these theorists, the central task of research is to describe the structure of these knowledge representations before and after change occurs and to provide accounts of the conditions and mechanisms responsible for restructuring.

Other researchers, such as Greeno and van de Sande (2007) and Leach and Scott (2008), take a more contextual perspective, grounding their views in sociocultural (Vygotsky, 1979) and situated (Brown, Collins, & Duguid, 1989) perspectives on learning. As Mason (2007) described, these theorists posit that

> knowledge is not an entity in the head of an individual, which can be acquired, enriched, or changed, but rather an activity that cannot be considered separately from the context in which it takes place. Therefore, learners do not accumulate knowledge from the outside, but rather participate in activities that are distributed among the individuals, tools, and artifacts of a community. (p. 2)

Similar to how these two stances are applied in literacy research, these approaches invoke different methodologies. Those who focus more on the individual characterize changes in mental representations through the methods of cognitive or learning sciences, whereas those on the more social side of the spectrum employ anthropological research methods to analyze discourse, activities, and contexts for keys to shifts in a community's language and practices.

Recently, the lines between these two perspectives have blurred considerably. Many current models of conceptual change now acknowledge that change occurs in the mind of a learner who is embedded within a broader sociocultural context, leading some to argue that the divide between these perspectives has begun to be bridged (Mason, 2007).

Models of Reading Comprehension

Despite the advances in our understanding of the phenomena of conceptual change, the identification of actual mechanisms that promote change has lagged behind other accomplishments. Recently, there has been renewed interest in identifying the mechanisms underlying conceptual change from a processing standpoint. Studies in text structure and text comprehension have led this movement.

Reading comprehension is a complex cognitive process that involves both lower (e.g., decoding, orthographic processes) and higher level processing of information to extract meaning from text (McNamara & Magliano, 2009). Multiple models of reading comprehension have been proposed and compared (e.g., see Israel & Duffy, 2008 for a more complete review of reading comprehension models). As one may imagine, a review of each of these models is beyond the scope of our purpose here. We focus on five prominent models of reading comprehension we believe to be applicable to conceptual change learning.

The models that we selected as being beneficial in providing a plausible association between text comprehension and conceptual change are the following:

- The Process Model (Kintsch & van Dijk, 1978)
- The Construction-Integration Model (Kintsch, 1988)
- The Resonance Model (Myers & O'Brien, 1998; O'Brien & Myers, 1999; O'Brien, Rizzella, Albrecht, & Halleran, 1998)
- The Constructionist Model (Graesser, Singer, & Trabasso, 1994)
- The Landscape Model (Tzeng, van den Broek, Kendeou, & Lee, 2005; van den Broek, Risden, Fletcher, & Thurlow, 1996; van den Broek, Young, Tzeng, & Linderholm, 1999)

Each of these models emphasizes the activation of the reader's relevant background knowledge during reading as well as the role of the reader in creating a coherent model of the text information. These models have a common thread that may provide a lens into the connection between text comprehension and conceptual change. Specifically, as the reader processes information in the text, his or her prior knowledge, which may include misconceptions, is activated. As the reader continues to process the text information, the reader may recognize an inconsistency between the prior knowledge and the ideas in the text, which in turn increases the likelihood of conceptual change.

We now turn to a review of the models that provide the theoretical underpinnings of recent empirical work in text comprehension and conceptual change.

The Process Model

The Process Model of reading comprehension, originally proposed by Kintsch and van Dijk (1978), provided the theoretical foundation for several more recent models of text comprehension. The Process Model emphasizes the importance of the reader forming a coherent representation of the text based on processing propositional units of text-based information. Propositions are posited to consist of one or more arguments (essentially concepts) and a relational concept (essentially the predicate). Text coherence results when the arguments in two propositions overlap. For example, the following two sentences demonstrate argument overlap: "The earth's axis is tilted at 23.5°. It is because of the tilt of the earth's axis that the seasons change." In this case, the argument, earth's axis, overlaps each of the two propositions. Argument overlap helps the reader connect the ideas within the text. The Process Model predicts that when the text has argument overlap among its propositions, successful text processing is likely to occur. When gaps exist due to a lack of argument overlap, the reader may make inferences to close the gap. Thus, the reader may add one or more propositions to develop a coherent text representation in memory.

The process of checking the text for referential coherence, and generating inferences among propositions when necessary, suggests that the text is processed in chunks of multiple propositions at a time. Segmented text processing is necessary due to the limited capacity of working memory. Propositions are processed in the order in which they are presented in the text. These propositions are processed in cycles, meaning that the propositions in the first segment are processed, then the segments in the second segment are processed, and so on. When a chunk of propositions is processed, some of the propositions are selected and retained in the short term memory buffer. According to this view, only those segments that are selected and stored in the buffer are available for relating the new incoming proposition segment with the previously processed information. When a connection is identified between the propositions stored in the buffer and the incoming propositions, the information is accepted as coherent. More specifically, if argument overlap exists between the propositions stored in the short term memory buffer and the incoming propositions, a coherent representation of the information will be formed. If the propositions do not overlap, then a search of all propositions previously processed, including those stored in long-term memory, is conducted.

The search process is successful when a proposition is found that shares an argument with at least one proposition in the next segment. When this occurs, the incoming segment is accepted and processing continues. However, if the cycle lacks argument overlap, an inference based on information currently active in memory may be added to connect the incoming segment with the previously processed propositions. Processing cycles continue in this manner as the reader constructs a coherent representation of the entire text.

The Construction-Integration Model

The Construction-Integration (CI) Model (Kintsch, 1988) is an updated model based on Kintsch and van Dijk's (1978) Process Model. Kintsch argued that discourse comprehension consists of two stages: (a) a construction phase in which a propositional network is constructed, and (b) an integration phase where the propositional network is edited and integrated into the reader's memory. Each of these phases, construction and integration, form the foundation of the CI Model.

The CI Model views reading as a bottom-up process in which the reader's prior knowledge is activated based on information from the text (construction phase) and integrated with ideas that are active in working memory (integration phase). As the reader proceeds through a text, information is parsed into phrases. As each sentence or phrase is read, it goes through a construction phase and then an integration phase. The integration of the text information and the reader's prior knowledge forms a propositional text base.

The reader's prior knowledge plays a central role in the CI Model. Knowledge is viewed as an associative net in which concepts or propositions are the nodes. These concepts can be directly related to ideas in the text or knowledge about linguistic rules. As a text is read, one sentence or phrase at a time, a set of concepts is activated. The activation level of concepts fluctuates systematically as the reader proceeds through the text. The activated concepts include those that are explicitly and inferentially activated by the sentence as well as concepts held over in working memory from the previous sentence. These concepts form a cluster of propositions that is derived from "a context-free process of activation of the closest neighbors of the original text-derived proposition in the general knowledge net" (Kintsch, 1988, p. 180). The resulting cluster of concepts may include irrelevant concepts. However, further spreading activation of concepts in the network will typically result in omitting the irrelevant concepts from further processing. The resulting memory representation is presumed to be a coherent representation of the text integrated with the reader's prior knowledge.

The CI Model assumes that multiple levels of memory representations are generated as part of the comprehension process (Graesser, 2007). One level of memory representation is the surface code, which keeps intact the syntax and wording of each sentence. A second level is the propositional text base. The text base preserves the meaning of each sentence by retaining the explicit propositions but omitting the surface code. A third level of memory representation is the situation model, sometimes referred to as the mental model. The situation model is the representation of the text that results from the integration of the content of the text and the reader's prior knowledge (Kintsch, 1988). It is the construction of the situation model that is central to text comprehension (Kintsch, 1986) and that plays an important role in conceptual change processes. The primary aim of refutation text is to provide the avenue whereby readers can reconstruct their existing knowledge to align with the scientific explanations provided in the text. Conceptual change is considered achieved when readers successfully integrate the text information with their prior knowledge as they generate a situation model that aligns with the scientific perspective.

The Resonance Model

A perspective that is consistent with aspects of Kintsch's CI model, as well as the memory-based text processing perspective (Gerrig & McKoon, 1998; McKoon & Ratcliff, 1992), is that of O'Brien and colleagues, who have explored the Resonance Model (Myers & O'Brien, 1998; O'Brien & Myers, 1999; O'Brien et al., 1998). O'Brien and colleagues (Albrecht & O'Brien, 1993; O'Brien & Albrecht, 1992) developed what they term the *contradiction paradigm* to test predictions of the memory-based perspective. In the contraction paradigm, readers are presented with descriptive background information about a protagonist. Some readers then encounter information that contradicts that background information. As an example, readers learn about a character, Mary, who is either a vegetarian or a fast-food junkie. Later in the narrative, Mary orders a cheeseburger. It takes readers longer to process that Mary ordered a cheeseburger if they have been exposed to information inconsistent with Mary's selection. So those who read that Mary ordered a cheeseburger after learning that she was a vegetarian take longer to process this inconsistent information than readers who encounter neutral or consistent (Mary was a fast-food junkie) information.

O'Brien and colleagues argued that the background information about Mary's food preferences is reactivated because it resonates with information in working memory (O'Brien et al., 1998). Exactly what information will resonate depends on the strength of the associations between the information in memory and the text features, such as elaboration. Specifically, they assumed "that this process is one in which concepts and propositions in the discourse representation and in the reader's knowledge base resonate as a function of the degree of match to the input" (Myers & O'Brien, 1998, p. 132). This is consistent with the CI Model's notion of argument overlap. However, the Resonance Model could be considered to be in greater accord with the memory-based text processing perspective (McKoon & Ratcliff, 1992). According to this view, readers try to maintain both local and global coherence, not just among text-based information but also between information in memory and information in the text. Therefore, information that is inconsistent with a reader's background knowledge can create a global coherence break, resulting in longer reading times or comprehension difficulties, *even if local coherence is maintained.* The Resonance Model suggests that readers try to maintain coherence and that they use information that is readily available to do so. According to this view, any information in memory that is related (even inconsistent information) is readily available to use in maintaining coherence.

In relation to refutation texts, the Resonance Model would predict that the refutation statement would explicitly resonate with the background knowledge of a reader who holds the misconception described in the text. Thus, when readers who hold a misconception read a refutation text, they are very likely to have the misconception readily available to integrate with the new information. Refutation texts are structured in a way that facilitates this process because the misconception will be readily available with no effort on the part of the reader. Refutation texts are structured in a way that helps the reader rebuild coherence by providing the explanation of the phenomenon in the next processing cycle. The reactivation of relevant, contradictory background knowledge and the attempt to reestablish global coherence provides a cogent possible explanation for the refutation text effect.

The Constructionist Model

The Constructionist Model of reading comprehension (Graesser et al., 1994) provides an additional perspective on text processing that may have implications for conceptual change. The Constructionist Model builds from assumptions about (a) reader goals, (b) explanation, and (c) coherence (Graesser, 2007). The reader goals assumption explains that readers attend most closely to the information in the text that aligns with their goals for reading the text. Deeper processing of text information is associated with the goal of constructing a coherent situation model. In contrast, superficial processing is associated with readers who have the goal of skimming through a text. For example, an astronomy text is read very differently when one is reading for pleasure versus studying for an exam in astronomy.

The explanation assumption states that readers typically seek to generate explanations for why actions occur in a text and why authors include particular ideas in a text. The model predicts that readers will consistently monitor how well they can generate coherent explanations based on the information in the text and their background knowledge.

The coherence assumption states that a reader will attempt to construct situation models that are coherent at both the local and global level. Consequently, if coherence gaps exist in a text, the reader generates inferences to fill in those gaps and construct a coherent representation. Graesser and colleagues (1994) argued that knowledge-based inferences generated online are critical building blocks of the situation models constructed by readers.

Knowledge-based inferences are constructed as the reader activates relevant background knowledge that is triggered by specific content words. These background knowledge structures are organized by meaningful relations and are constructed through experience (Graesser et al., 1994). The model predicts three classes of knowledge-based inferences that are routinely generated during reading in an attempt to achieve explanatory coherence. Causal antecedents explain why an event, action, or state is explicitly presented in the text, while character goal inferences motivate specific actions in the text. A reader may also generate global thematic inferences that convey the gist of a message. The model specifies two additional types of inferences, predictive and elaborative, that may be generated during reading if the text lacks coherence or the reader lacks relevant background knowledge needed for constructing an explanation and global coherence.

Comprehension is successful when the reader generates inferences that are relevant and accurate. The Constructionist Model also states that comprehension is successful when the reader is able to discern whether incoming information contradicts or is irrelevant to information presented earlier (Graesser et al., 1994). This prediction of the Constructionist Model is especially relevant to refutation text and conceptual change. Indeed, conceptual change researchers argue that change is more likely to occur when an individual notices the discrepancy between his or her prior knowledge and the scientific explanation (Chi, 2008; Limón, 2001).

Refutation texts are written to explicitly state a common misconception and then directly refute it (Hynd, 2001). When the individual reads the misconception sentence, the reader's relevant background knowledge is activated. If that background knowledge aligns with the misconception presented in the text, then as the reader proceeds through the text, he or she is likely to notice the contradiction between the background knowledge and the scientific explanation. The Constructionist Model (Graesser et al., 1994) predicts that once readers recognize the contradiction, they will strive to achieve explanatory coherence through generating inferences. It is possible that explanatory coherence may foster conceptual change as the reader constructs a coherent situation model that aligns with the accepted scientific explanation. However, it is also possible that the reader may construct a coherent but incorrect situation model.

The Landscape Model

An additional model of reading comprehension, the Landscape Model (Tzeng et al., 2005; van den Broek et al., 1996; van den Broek et al., 1999) provides more specific insights into comprehension and conceptual change. Similar to the Process Model (Kintsch & van Dijk, 1978), and consistent with aspects of the Resonance Model, the Landscape Model focuses on the reader's ability to generate a coherent representation of the information presented in the text. As the reader proceeds through the text, concepts (e.g., propositions) are processed in cycles. However, because of the limited attentional capacity of working memory, a reader may only attend to a subset of the concepts at any one time. van den Broek and Kendeou (2008) explained, "As the reader proceeds through the text, concepts (propositions, informational units) fluctuate in activation: With each new cycle some concepts (e.g. sentence) continue to be active, others decline in activation, and yet others become newly (re)activated" (p. 338). Four sources of information influence the fluctuations in concept activation: (1) text information in the present processing cycle, (2) residual text information carried over from the previous cycle, (3) the representation constructed of the text thus far, and (4) the reader's prior knowledge, which may include misconceptions. These sources of activation, in combination with limited attention capacity, cause concepts to continually fluctuate in activation during reading.

Within the Landscape Model (van den Broek et al., 1999), two types of mechanisms are postulated to guide access to activation of concepts from the reader's prior knowledge, and for the memory representation of the text constructed by the reader. The first mechanism is cohort activation, which is the process by which concepts that are associated with the currently activated concept are also activated. This process is in accord with the Resonance Model's perspective of activation of related prior knowledge. For example, if the concept of the day/night cycle is activated, the reader may activate associated concepts from prior knowledge, such as sunrise and sunset. Cohort activation is memory based and occurs automatically without the conscientious effort of the reader (van den Broek & Kendeou, 2008).

The second mechanism for concept retrieval is coherence-based retrieval (van den Broek et al., 1999). In contrast to the passive, automatic nature of cohort activation, coherence-based retrieval is strategic, employed by the reader with the goal of forming a coherent memory representation of the text. For example, when information in a text is unfamiliar to the reader or difficult for the reader to understand, the reader will search for additional information with the goal of forming a coherent mental representation. Coherence-based retrieval occurs during reading as the reader seeks information from either the text, prior knowledge, or the text representation constructed thus far.

The reader's standards of coherence, or standards for what the reader perceives as adequate comprehension, determine in part whether coherence-based retrieval processes or cohort activation processes are invoked (van den Broek & Kendeou, 2008). If the reader's standards of coherence are met by the information activated at each cycle, reading progresses without employing retrieval strategies. However, when cohort-activated concepts do not meet the reader's standards of coherence, the reader may actively search prior knowledge and the text-based mental representation generated thus far to maintain coherence.

The patterns of activation are central to comprehension within the Landscape Model. Through this process, the text information and the reader's prior knowledge are integrated to form a memory representation of the text. The particular concepts that are activated at each reading cycle are added to the developing text representation. If a concept is reactivated, the memory trace is strengthened. "When concepts are co-activated in a cycle a connection between these concepts is established (or strengthened, if a connection already existed)" (van den Broek & Kendeou, 2008, p. 339). Cohorts are formed through the connected concepts, and these are the basis for cohort-activation.

The coactivation process within the Landscape Model provides insights into the connection among reading comprehension, misconceptions, and conceptual change. Within the model, only those concepts that are coactivated can be compared, contrasted, retained for further processing, or integrated (van den Broek & Kendeou, 2008). The opportunity for coactivation is brief because concepts activated in one cycle may not carry over into subsequent processing cycles. To foster conceptual change, it may be essential for the reader to activate the relevant misconception at the same time as the scientifically correct concept. The coactivation of the misconception with the scientifically correct concept increases the likelihood that the reader will notice the discrepancy between the two, which in turn facilitates conceptual change (Guzzetti, Synder, Glass, & Gamas, 1993; Kendeou & van den Broek, 2007). Thus, the coactivation hypothesis provides one potential explanation of the power of the refutation text effect to promote conceptual change. Indeed, the coactivation hypothesis has considerable empirical support from think-aloud protocols (Kendeou, Muis, & Fulton, 2010; Kendeou & van den Broek, 2007), reading time and computational data (van den Broek & Kendeou, 2008), and more recently, eye-tracking data (Ariasi & Mason, 2010; Kendeou, 2009).

Empirical Studies Exploring the Refutation Text Effect

Research on the effect of text structure on changing students' conceptions about scientific content has had a long and productive history (for an excellent recent review, see Tippett, 2010) that dates back prior to the development of some of the process models just reviewed. During the 1980s and 1990s, the emphasis of this research was on the potential power of text as an instructional intervention to promote knowledge change (e.g., see Hynd & Alvermann, 1986).

A major focus of this research was on determining what types of text structures were most powerful for promoting change. Among the structures examined were traditional expository texts; persuasive texts, including dual and single positional texts; and refutation texts (Guzzetti et al., 1993). Traditional expository texts may present information in a list-like fashion with little support to help the reader form connections between the series of related but discrete topics (Mikkilia-Erdmann, 2002). In contrast, persuasive texts are designed to shift readers' attitudes toward a topic or event. One-sided persuasive texts present only those arguments and evidence that the author hopes the readers will adopt. Dual position persuasive texts present both sides of an issue but provide more evidence and make stronger arguments for one side over another without explicitly stating it as the preferred stance (Hynd, 2001). Refutation texts are considered to be persuasive in nature because they present a compelling argument that is designed to shift the reader's views to the accepted scientific viewpoint.

Refutation texts are those that provide an explicit statement of a commonly held misconception followed by a direct refutation of that misconception.[1] So a refutation text about seasonal change might address the common misconception about why seasons change by stating, "Some people think that seasons change because the Earth is closer to the sun in summer and farther away from the sun in the winter." A direct refutation of this misconception and an explicit statement of the current scientific explanation would then follow the statement of this common misconception. So in our example, after the explicit statement of the misconception, the text would go on to explain, "However, this is not the case. Rather, it is the tilt of the Earth's axis that causes the seasons to change." The text would then likely go on to further explain the phenomenon of seasonal change.

The early research on text structure and conceptual change culminated in a meta-analysis by Guzzetti and colleagues (1993) that reviewed the evidence for the effectiveness of several conceptual change interventions, including refutation texts. The evidence suggested that refutation texts were the most effective in promoting conceptual change among those interventions included in the meta-analysis. Whereas results of some of the subsequent research have been mixed, refutation texts have shown two consistent advantages: maintenance effects and likability. Studies that use refutation texts as a conceptual change intervention often show a maintenance effect; that is, the conceptual change effect persists for weeks (Hynd, McWhorter, Phares, & Suttles, 1994) or even months (Mason & Gava, 2007) post intervention. Also, students often report a preference for the format (Hynd, 2001; Mason, Gava, & Boldrin, 2008).

In regard to explanations for the refutation text advantage over other interventions, the studies from this era focused more on whether the texts were effective and less on explaining the nature of the refutation text effect. Indeed, the majority of the studies conducted during this time focused on conceptual change outcomes as the result of reading refutation text, rather than on cognitive processes associated with facilitating change. For example, refutation text was more effective than hands-on demonstrations or discussions for promoting conceptual change (Hynd, Alvermann, & Qian, 1997; Hynd et al., 1994). Similarly, Diakidoy, Kendeou, and Ioannides (2003) showed that students who read refutation text embedded within traditional science classroom instruction (e.g., direct instruction) were more likely to experience conceptual change than students who read expository texts embedded within traditional science instruction. Outcome-focused studies have also demonstrated that refutation texts may facilitate construction of new mental models that align more closely with the scientific explanation (Diakidoy et al., 2011; Mikkilia-Erdmann, 2002; Skopeliti & Vosniadou, 2008), and that this effect may be the result of deeper cognitive processing of the text, prompted by a comparison between existing knowledge and the information in the text (Mason et al., 2008). For example, in an investigation of text structure differences on learning outcomes and reading comprehension, Diakidoy and colleagues (2011) found that individuals who read refutation texts tended to construct more coherent and elaborated representations of textual information than individuals who read expository text. A common thread across these and other outcome-focused studies was that the activation of students' prior knowledge was a key factor leading to the effectiveness of refutation texts (Tippett, 2010). The emphasis of outcome-focused investigations and the lack of process-focused investigations motivates the call for moving forward into studies examining the nature of the refutation text effect.

After the Guzzetti et al. (1993) meta-analysis was published, research on text and conceptual change seemed to wane. Perhaps the increased interest in inquiry instruction, as noted earlier, led to the tapering off of interest in research on text-based interventions in science. However, recently there has been a flurry of renewed interest in text in the science classroom in general (Broughton & Sinatra, 2010), and in refutation text in particular (Tippett, 2010). The renewed interest in refutation text as a tool for promoting conceptual change has sparked investigations related to process explanations of how refutation texts may facilitate conceptual change. Based on the theoretical models reviewed earlier, possible mechanisms that researchers have begun to explore include coactivation, attention allocation, text coherence, and the nature of the information provided in the refutation text. In the following section, we review the empirical evidence for each of these accounts of the refutation text effect.

Coactivation

The Landscape Model (van den Broek et al., 1999) provides the explanatory framework for several studies that explore the refutation text effect (e.g., Kendeou & van den Broek, 2005, 2007). Central to the Landscape Model is the process of coactivation. As noted, as a reader progresses through a text, information from four sources can fluctuate in activation: (1) information that has just been read in the text, (2) residual text information from the prior cycle, (3) the mental model constructed thus far, and (4) the prior knowledge of the individual. Conceptual change is most likely to occur when the reader's misconception is activated at the same time as the scientific explanation. Coactivation of the misconception and the scientific explanation provides the reader with the opportunity to integrate the two conceptions. It may also promote deeper engagement with those contrasting views and thereby increase the likelihood of conceptual change (Dole & Sinatra, 1998).

Kendeou and van den Broek designed a series of studies to examine how readers process different types of texts and how those processes may influence conceptual change. In the first study (Kendeou & van den Broek, 2005), participants' misconceptions, or inaccurate ideas, were assessed to determine the quality and quantity of those misconceptions and their impact on comprehension. Sentence-by-sentence reading times were also recorded for each participant. The results showed no differences in reading time between participants with misconceptions and participants without misconceptions. The findings indicated that readers with misconceptions employed many of the same online reading processes (e.g., elaborating, inferring, summarizing) as readers without misconceptions. However, the offline measure analysis showed that participants with misconceptions generated significantly fewer accurate explanations than participants in the nonmisconception group. Moreover, the offline measure results indicated that misconceptions were interfering with readers' text recall. Readers without misconceptions generated more correct inferences and recalled more text information than readers in the misconception group.

A subsequent study examining the effects of readers' misconceptions and text structure on reading comprehension (Kendeou & van den Broek, 2007) provided further insights. Participants read either a refutation or expository text that each described Newton's first and third laws of motion. Reading times were again recorded. The findings indicated that readers who had misconceptions were more likely to notice the conflict between their prior knowledge and the scientific explanation, and attempt to resolve that conflict, when they read the refutation text. This result provided support for the coactivation hypothesis, namely the notion that coactivation of the reader's misconceptions and the information in the text facilitates conceptual change learning. Furthermore, these results suggest that refutation texts may be more likely to spark the coactivation process than traditional expository texts.

An important outcome of this series of studies on text processing and text structure is the reading time data. It is of interest to note that the findings of the Kendeou and van den Broek (2005) study showed no difference in reading times between those with misconceptions and those without misconceptions. However, the outcomes of the subsequent studies (Kendeou & van den Broek, 2007; van den Broek & Kendeou, 2008) showed a significant difference in reading times between the two groups when reading the refutation text. Participants with misconceptions read the refutation text slower than readers without misconceptions. These results suggest that the refutation text format increases opportunities for coactivation of the reader's prior knowledge and the text ideas. Consistent with the findings of O'Brien and colleagues (e.g., see Albrecht & O'Brien, 1993; O'Brien, 1995), a target sentence that contains a refutation (i.e., contradicts background knowledge) serves as a signal that activates contradictory background knowledge. Coactivation may in turn lead the reader to detect and possibly resolve conflicts between their prior knowledge and the textual information, in turn providing opportunities to engage in efforts to resolve the conflict (van den Broek & Kendeou, 2008). The opportunities for coactivation and integration of the reader's prior knowledge likely increase when reading a refutation text. Thus, the structure of expository texts may not foster coactivation even in those instances where the reader has conflicting prior knowledge, because unlike refutation text, the expository text does not present the misconception, and thus is less likely to activate contradictory background knowledge.

Attention Allocation

Further investigations of the relation between comprehension processes and text structure have led researchers to investigate attention allocation during reading. For example, Broughton, Sinatra, and Reynolds (2010) examined the relationship between conceptual change and time spent reading either a refutation text or an expository text. Undergraduate students read either a refutation text or a traditional expository text on the causes for seasonal change on Earth. Similar to the Kendeou and van den Broek (2005, 2007) studies, participants' reading times were recorded.

The findings showed that participants allocated their attentional resources differently between the two types of texts. Participants who read the refutation text read at a faster rate than participants who read the expository text. Specifically, participants read the refutation segment significantly faster than the comparable sentences in the expository text. As the reading times were faster rather than slower, as found in some of the other process studies of refutation texts (Ariasi & Mason, 2010; Kendeou & van den Broek, 2007), Broughton et al. (2010) interpreted their findings as consistent with research on text processing and interest. When readers find a text segment particularly interesting, they can show faster reading times (Lehman, Schraw, McCrudden, & Hartley, 2007). Follow-up interviews with the participants in the Broughton et al. (2010) study suggested that readers found the refutation sentence interesting, shocking, and in contrast to what they knew. The interest-generated attention paid by readers to the refutation segments may have promoted conflict between the readers' prior knowledge and the scientific explanation. This finding provides support for the notion that the refutation segments are processed in a manner that demands greater attention, enhancing their potential for promoting conceptual change.

The structure of the refutation text may also guide the reader in allocating attentional processes. For example, a critical sentence of a refutation text is the statement of a common misconception intended to activate the reader's relevant prior knowledge (Hynd, 2001). The stated misconception may serve as an advance organizer by activating prior knowledge and providing an organizational framework for the reader (Ausubel, 1968). The misconception may signal rhetorically to the reader that the subsequent text information is significant (Broughton et al., 2010), which may lead to increased processing as the reader shifts attentional resources to search for the significant information.

It is also possible that readers allocate attentional resources to information in the refutation text that they deem relevant. Readers can determine relevance based on prereading instructions, they may set their own criteria before reading, or they may determine the criteria as they begin reading. According to this view, relevant information signals the reader to focus on specific information in the text. It is important to note, however, that it is likely that both relevant and irrelevant concepts are activated at the onset of reading the refutation text. Irrelevant concepts fade away quickly as the reader allocates attention toward the relevant information (Gerrig & O'Brien, 2005; O'Brien & Myers, 1999). From a conceptual change standpoint, the additional attention allocated to relevant information increases opportunities for the reader to make a comparison between their prior knowledge and the scientific explanation.

The refutation text structure has an advantage in that it should be clearer to the reader that information contradicting their background knowledge is relevant. This should increase the likelihood that the reader draws a comparison between the misconception and the scientific explanation. In addition, because the refutation sentence directly refutes the misconception, this may lead the reader to allocate additional cognitive resources to relevant information in the scientific explanation as they strive to resolve the discrepancy between those two views. The contradiction paradigm (Albrecht & O'Brien, 1993; O'Brien & Albrecht, 1992) predicts that readers' cognitive processing will slow down when they read the refutation sentence because that sentence reactivates relevant background knowledge. If the reader notices the contradiction between the refutation sentence and the discrepant background knowledge, attentional resources can be allocated to resolving the contradiction and generating a situation model that aligns with the scientific explanation.

Exploring Text Coherence Through Eye-Tracking Methodologies

Conceptual change researchers have begun using eye-tracking methodologies to investigate the interrelationship between text processing, reading comprehension, and conceptual change. Eye-tracking methodologies allows researchers to capture the reader's eye movements, or *saccades*, as well as their *fixations* (200–300 millisecond pauses) as text is read (Rayner, 1998). Saccadic movements between sentences and fixation times provide insights into comprehension difficulties. In other words, where a reader directs his or her attention is revealed by saccadic movements, and how much attention is allocated is revealed by fixations. Regressions suggest comprehension difficulties (Mikkila-Erdmann, Penttinen, Anto, & Okinuora, 2008), which are revealed through examination of eye movements, particularly across sentence boundaries (Hyona, Kaakinen, & Lorch, 2002). For example, eye-tracking researchers have found that regressions increase as the need to resolve semantic or syntactic ambiguities in a text increases (see for example, Hyona et al., 2002; Rayner, 1998).

In relation to conceptual change and refutation texts, readers' eye movements reveal when they encounter information that contradicts their prior knowledge. It is likely that when readers notice a discrepancy between prior knowledge and the information in the text, they have difficulty constructing the text representation or the situation model (Mikkila-Erdmann et al., 2008). Misconceptions may be a source of ambiguity for the reader if they are independently activated or coactivated as a result of the refutation text structure. Researchers are beginning to investigate the association between eye movements during reading refutational texts and the subsequent relationship with conceptual change.

A study conducted by Mikkila-Erdmann and colleagues (2008) investigated whether cognitive conflict could be traced during reading using eye-tracking methodology. The researchers predicted that cognitive conflict would be associated with increased reading times and increased total fixation times. In addition, the researchers explored whether reading processes, as tracked through eye movements, would differ between refutation texts and traditional expository texts. Participants were randomly assigned to read either the refutation text or the expository text, as presented on a computer screen. Participants' eye movements and reading times were recorded. Participants completed written pretests and delayed posttests to determine whether conceptual change occurred. Their responses were analyzed on the level of knowledge change as a result of reading the text. Participants were grouped based on the level of change from pretest to delayed posttest. Two groups were identified for further analysis: those who did not experience conceptual change and those who showed conceptual change to some extent.

Results showed that readers who experienced conceptual change had increased reading times in comparison to participants who did not. Specifically, those who experienced conceptual change showed longer total fixation times and longer regression times. Most important was the fact that those who experienced conceptual change showed longer "look from" times (returning to previous text *from the critical part* of the text) than those who did not experience conceptual change. This finding suggests that when readers come to a critical part of a text, they will likely return to previous sections of the text in an attempt to resolve any ambiguity that may have arisen from the critical portion of the text. Regressive eye movements that occur when anomalous information is encountered would be consistent with predictions based on memory-based models, as well as coactivation and attention allocation perspectives (Broughton et al., 2010; O'Brien & Myers, 1999; van den Broek et al., 1999).

A similar study using eye-tracking methodology to investigate cognitive processes and conceptual change was conducted by Ariasi and Mason (2010). The aims for this study were to investigate whether differences in attention allocation existed based on text structure and, if so, which parts of the text would receive additional attention. Participants read either a refutation text or an expository text presented on a computer screen. Eye movements and reading times were recorded for each participant.

Results showed that readers in the refutation text group spent less time reading the refutation section during their first reading of that section than readers in the expository group who read comparable sentences. However, readers in the refutation text group spent significantly more time rereading the sentences containing the scientific explanations than the expository text group. In addition, participants in the refutation text group reread the refutation sentences more frequently while reading the science concepts than participants in the expository group with comparable sentences. This finding suggests that the refutation sentence may spark cognitive conflict when a reader holds a misconception about the topic, and that the reader rereads the refutation sentence in an attempt to construct a coherent mental model of the phenomenon. These results raise the question of whether the participants in the Broughton et al. (2010) study would have also reread the refutation sentence if they had had the opportunity to look back in the text. This should be explored in future research as the pattern that is emerging across these studies suggests that reading a refutation text triggers mechanisms that promote and support conceptual change.

Type of Information Within a Refutation Text

Much of the research on refutation text as an avenue for promoting conceptual change has focused at the level of text structure (i.e., expository versus refutation). Recently, researchers have begun to examine refutation texts at a more fine-grained level to explore whether the type of information included in a refutation text can be more or less effective in promoting conceptual change. Specifically, Skopeliti and Vosniadou (2008) manipulated the kind of scientific information in a refutation text to include either categorical information or noncategorical information. Categorical information refers to information about which category a specific concept should belong to conceptually. For example, Skopeliti and Vosniadou included categorical information about the Earth being a solar object rather than a physical object.

Participants read one of the following: (a) a refutation categorical text, (b) a refutation noncategorical text, (c) an expository categorical text, or (d) an expository noncategorical text about the earth. The refutation categorical text described the Earth as a solar object and not a physical object, with characteristics like those of other solar objects, including revolving around the sun and being round in shape. The refutation noncategorical text described how the Earth is round although it may look flat because we live on it and see its surface at a very close range. The expository texts mirrored the refutation texts in content with the exception that they did not contain a refutation sentence. Results showed that the expository categorical group outperformed the expository noncategorical group. However, the refutation categorical text group experienced higher levels of conceptual change than did any of the other groups. In other words, students who read the refutation categorical text experienced a greater shift in conceptual knowledge about the Earth as a solar object than students who read the refutation noncategorical text. These findings suggest that including categorical information in refutation texts may be more effective in promoting conceptual change than that of noncategorical refutation texts because of the learner's implicit beliefs within categorical information that can influence new learning.

Future Directions

We began this article with three objectives: (1) to introduce readers to the revitalization of researchers' interest in text for promoting conceptual change, (2) to draw attention to the benefits of text in the science classroom, and (3) to inspire multidisciplinary research at the crossroads of text comprehension and conceptual change. Toward this third goal, in this section we suggest future directions for researchers pursuing theoretical issues, methodological advances, and instructional innovations.

Theoretical Issues

The research on refutation texts has moved from explorations of effectiveness toward the development of text processing explanations accounting for the refutation effect. We reviewed several perspectives on comprehension, which provide credible and cogent possible explanations for how and why refutation texts promote conceptual change. In addition, empirical support for these perspectives has begun to coalesce into an explanation based on a reader's attempts to maintain coherence among text elements and background knowledge. Several important theoretical issues remain for future research.

An important theme throughout our review of research on conceptual change, models of text comprehension, and the refutation text effect is the degree to which each of these processes are more commonly "bottom up"—that is, driven by development, context, experience, and text structure—or whether they are more typically "top-down" processes initiated and controlled by readers' goals, intentions, and strategic processing. In our view, both conceptual change and comprehension are interactive processes. That is, when at their most successful, comprehension and conceptual change involve a complex interplay of both bottom-up and top-down processes, unintentional and intentional, and automatic and self-regulated processes. Researchers with an eye toward moving the field forward should explore how these interactions play out when reading about information that conflicts with prior knowledge.

An interesting theoretical question that is at the heart of this interaction is the relationship between coherence breaks and cognitive conflict. As readers attempt to comprehend a science text, they likely encounter text elements (such as coherence breaks or refutation statements) that trigger some automatic activation of conflicting background knowledge. Conceptual change researchers, however, describe the experience of cognitive conflict as a reflective process that occurs when learners *realize* that their background knowledge is not in accord with scientific perspectives. The text processing models we reviewed, along with their empirical support, give reason to hypothesize that coherence breaks may promote cognitive conflict, although as of yet there is no research to support this contention. Coherence breaks and cognitive conflict, at least as they are discussed in the comprehension and conceptual change literatures, are significantly different processes. Whether readers are actually experiencing cognitive conflict at the moment they encounter a coherence break or a refutation statement is an interesting, as yet unexplored question. It seems that attempts to repair a coherence breakdown are initiated and conducted with little effort and few resources, while the experience of cognitive conflict is more in line with accounts of strategic reading. Certainly, encountering a coherence break and attempting to resolve the discrepancy, reestablish coherence, and integrate text elements with background knowledge may trigger a more reflective experience of cognitive conflict. However, once a reflective process of cognitive conflict begins, many other factors come into play, such as a reader's motivation for learning or for resisting the new idea. A combination of online and offline postreading measures, as were used in several of the studies reviewed, may be best to further explore the intriguing relationship between these coherence breaks and cognitive conflict.

A second theoretical question of interest is whether refutation text benefits both comprehension and conceptual change processes. That is, it seems clear that refutation text can provide an advantage for conceptual change, but less explored is whether refutation text provides an advantage for comprehension. There is indirect evidence, based on the large number of studies that show a learning advantage for reading refutation text, that it is relatively easy to understand and promotes comprehension of the content. And as noted earlier, research has demonstrated that readers prefer the refutation format (Tippett, 2010), not a small matter when motivation to read scientific material may be lacking. But whether refutation text provides some advantage for promoting comprehension is not exactly clear. Research has demonstrated that texts with coherence breaks can require more effortful processing on the part of the reader, and greater comprehension may result (McNamara, Kintsch, Songer, & Kintsch, 1996). In several experiments using science texts, McNamara and colleagues have demonstrated that readers with high levels of background knowledge can actually perform better on low coherence texts depending on their reading skill level (McNamara, 2001; McNamara et al., 1996; Ozuru, Dempsey, & McNamara, 2009). These results were attributed to the effort that readers must exert to construct inferences and build coherence, which draws readers away from a passive reading strategy toward a more active one. If readers of refutation text exert effort to build a coherent situation model, this would likely facilitate both comprehension and conceptual change. It may be that readers with relevant background knowledge, even if it is in the form of misconceptions, exert effort to rebuild coherence after reading contradictory information. Thus, they are likely to engage in deeper levels of processing, which would promote comprehension as well as conceptual change.

A third theoretical question surrounds *hot constructs* and their role in the comprehension of conceptual change text. Recent interest in the role of motivation in both comprehension and conceptual change has dramatically increased since the earlier work in refutation text. Recent work in conceptual change has been exploring the "warming trend" (Sinatra, 2005, p. 107), or the role of emotions, motivations, and other hot constructs in promoting or inhibiting conceptual change. Students often perceive topics in science, such as stem cell research, climate change, and evolution, to be controversial, and as such, they may have negative attitudes or emotions promoting resistance to conceptual change (Sinatra & Mason, 2008). Students in the Broughton et al. (2011) study showed strong negative attitudes and emotions toward the scientists' decision to reclassify Pluto. The negativity decreased following reading a refutation text about Pluto's reclassification. Because students reported that they appreciate the refutation text format, the motivational aspects of using refutation text as a component of scientific literacy instruction is worthy of investigation.

Methodological Advances

The strategy of using eye tracking has significantly advanced our understanding of the refutation text effect. The advantage of this methodology for the study of refutation text is that researchers can examine how readers cope with the discrepant information they encounter at the moment they encounter it. More studies using this methodology may help to elucidate the text processing mechanisms involved in resolving the type of processing that reading a refutation text engages.

Researchers have begun to use online tracking systems for monitoring learners in online learning environments. One such system, iSTART (Interactive Strategy Trainer for Active Reading and Thinking; McNamara, Levinstein, & Boonthum, 2004) helps students comprehend by constructing self-explanations of the text, a strategy known to promote conceptual change (Chi, deLeeuw, Chiu, & LaVancher, 1994). This would be an excellent environment in which to explore the refutation text effect. Some online learning environments provide rich information not only about where readers direct their gaze but also about what types of learning strategies readers employ (Winne, 2006). Some, such as AutoTutor, (Graesser, Chipman, Haynes, & Olney, 2005) even monitor students' emotions in real time by monitoring physical movements (i.e., shifting in their seats) or by employing physiological measures such as heart rate (D'Mello & Graesser, 2011). Online tracking of students engaged in Web-based learning environments can provide rich forms of data to explore the complex questions that need to be addressed, such as the following:

- What are students' emotional reactions to reading text that conflicts with their knowledge?
- Do coherence breaks lead to cognitive conflict?
- What are the reciprocal effects of comprehension and conceptual change?

There are many other methodological techniques that could enhance our understanding of comprehension and conceptual change. For example, think-alouds could be used to explore readers' interpretations of their experiences when they encounter information that conflicts with their background knowledge. Interviews post reading have shown some promise for pinpointing which features of the text were of more interest to readers and why (Broughton, et al., 2010). Indeed, the role of text in conceptual change can be explored through a variety of theoretical lenses and research methods. We encourage researchers to use multiple mixed methods to more fully explore comprehension and conceptual change.

Instructional Issues

In addition to theoretical and methodological questions regarding text processing and conceptual change, there are important instructional questions that warrant attention. How best to enhance the power of refutation texts is one question worth exploring. We have seen that the refutation text effect can be augmented by discussion interventions (Broughton et al., 2011; Poliquin, Nussbaum, Sinatra, & Putney, 2010). In a recent study focused on elementary students' emotions when learning about science (Broughton et al. 2011), students learned about Pluto's demotion to dwarf planetary status. Those who both read a refutation text and engaged in a teacher-led, small group discussion based on a questioning the author model (Beck, McKeown, Hamilton, & Kucan, 1997) experienced greater conceptual change about planets, greater attitude change about Pluto's reclassification, and a reduction in negative emotions as compared with those who only read the refutation text. Refutation text can also be augmented with argumentation strategies that have been shown to be effective in promoting conceptual change (Nussbaum & Sinatra, 2003; Nussbaum, Sinatra, & Poliquin, 2008; Poliquin et al., 2010). More research is needed on how best to increase the value-added benefit of refutation text for promoting science learning.

As we noted, early work on instructional issues with refutation text focused on the structure and format (e.g., two-sided refutation, dual positional; Tippett, 2010). The more recent work has focused on how the content can be designed to enhance its effectiveness. Skopeliti and Vosniadou (2008) focused on drawing readers' attention to the type of conceptual change required (recategorization). In the Broughton et al. (2011), we augmented the information regarding Pluto's reclassification with nature of science content (Smith & Scharmann, 1999). Broughton et al. (2011) found this helped students appreciate the scientists' rationale for the reclassification. Further work on the effectiveness of the refutation text for promoting conceptual change should focus on how informational content can be augmented to increase the refutation text advantage.

An obvious area ripe for future study is the use of refutation text to promote conceptual change in domains other than science. We know of no studies that have explored the role of refutation text in areas such as social studies. Certainly, persuasive texts have been used instructionally in many domains (Murphy & Mason, 2006) to promote belief change. And researchers have explored conceptual change in areas outside of science, such as mathematics (Vamvakoussi & Vosniadou, 2004, 2007) and history (Limón, 2003). But explorations of the potential of refutation text in domains other than science are sorely lacking.

Conclusions

We began this article by arguing that choosing whether to promote reading comprehension or science learning is a false and misguided decision. The research presented here suggests that text comprehension, particularly of text designed to promote conceptual change, is one promising avenue for promoting both forms of literacy. Readers who seek to comprehend refutation text through the mechanisms of maintaining coherence or resolving cognitive conflict are likely to experience both comprehension and conceptual change. Therefore, greater integration of research and instructional practice in these two areas is likely to advance both scientific literacy and comprehension development.

Research in the areas of comprehension and conceptual change has recently crossed paths in a way that is timely, both theoretically and practically. Theoretically, each area of research has the potential to contribute to greater understanding of the mechanisms involved in text processing and knowledge restructuring in ways that may advance our understanding of both. In a practical sense, integration of comprehension and science content instruction can contribute to literacy instruction and help educators increase instructional time on science content, a win-win for science and literacy instruction. We hope that future investigations bridging comprehension and conceptual change research will prove fruitful for learning in science as well as other domains.

Notes

[1] We use the term *misconception*, as it is often used in the conceptual change literature, to refer to notions that are in conflict with accepted scientific explanations of phenomena. Many other terms are used in the literature, including "alternative belief, alternative conception, alternative framework, children's science, erroneous idea, inaccurate prior knowledge, intuitive conception, intuitive science, naïve conception, naïve theory, nonscientific idea, persistent pitfall, preconception, preinstructional conception, and spontaneous reasoning" (Tippett, 2010, p. 953).

We would like to extend our thanks to the reviewers for their helpful comments.

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Gale M. Sinatra is a professor in educational psychology in the Rossier School of Education at the University of Southern California, Los Angeles, USA; e-mail gsinatra@usc.edu.

Suzanne H. Broughton is an assistant professor of literacy in the School of Teacher Education and Leadership at Utah State University, Logan, USA; e-mail suzanne.broughton@usu.edu.

Erratum

The publisher regrets an error that appeared in Table 2 of “Educational Effects of a Vocabulary Intervention on Preschoolers’ Word Knowledge and Conceptual Development: A Cluster-Randomized Trial” by S.B. Neuman, E.H. Newman, and J. Dwyer, 2011, *Reading Research Quarterly*, *46*(3), pp. 255–256. In the “Vocabulary” column, the boldface italicized words are the target vocabulary words, and those simply in italics are supporting words. None of the words should have been underlined.