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Text Coherence, Reading Ability, and Children's Scientific Understanding*

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The purposes of this study were (1) to examine whether principles of revision that improve the coherence of text, which have been used successfully on texts for advanced readers, can also be used in revising young readers' texts; (2) to investigate whether the principles used to revise history texts can be applied to scientific texts and (3) to look at the interaction between text coherence and reading ability. Two authentic scientific texts (on diabetes and on pain) were revised according to four revision principles, *providing argument-overlap, making implicit concepts explicit, changing order of sentences and paragraphs, and adding macro-structure to the text*. Ninety-one 6^{th}-grade students were divided into low-ability and high-ability groups and randomly assigned to read either the original texts or the revised texts. Participants' comprehension was measured by free recall, questions assessing knowledge of the textbase (which assessed a shallow level of comprehension), and inference questions (which assessed a deep level of comprehension). Results indicated that young readers' comprehension was superior when the coherent version of the texts was read. High-ability readers performed better than low-ability readers. A significant interaction between text coherence and reading ability emerged on the inference questions for one of the texts. That is, low-ability readers' performance on the inference questions was better when the text was coherent, whereas high ability readers' performance was not improved by making the text coherent. Thus the text coherence affected the deep comprehension level of these low-ability readers. This finding is discussed in terms of its educational implications.

KEY WORDS: reading ability, reading comprehension, text coherence

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Many students find scientific texts particularly difficult to understand. Why do they have difficulties? Is the nature of scientific texts different from narrative or other expository texts? Perhaps the most important reason is that scientific texts usually involve new, dense concepts with which readers are unfamiliar (Barton, Heidema, & Jordan, 2002). Scientific texts involve complex mechanisms with multiple components, attributes of components, and relations between components (Graesser, Leon & Otero, 2002). The language in the texts is usually different from students' daily experience. Students have difficulty in assimilating the new information into their own knowledge structure. Hence, it is not easy for students to construct a meaningful mental representation. These problems are especially serious for young students with little reading ability and scientific knowledge.

Students typically begin to learn from text at the fourth grade. At this time, young students read both narrative and expository texts. Most teachers and educators believe that students at this age are already capable of acquiring new information by reading expository texts. However, many students still fail to understand expository texts because they do not possess competence in understanding unfamiliar text features, such as unfamiliar vocabulary, difficult concepts and complex organization. They cannot process the incoming written information, retrieve background knowledge, and hold both in working memory and produce useful inferences for understanding the text. This lack of competence brings about difficulties of understanding expository texts. Thus, several practical questions have emerged: Does reading ability account for the failure of understanding expository texts? Are competent readers more capable of handling expository texts, especially scientific texts? If, unfortunately, many young students are not able to process scientific texts, how can we improve the texts and students' understanding?

Scientific Texts and Historical Texts

Early research on text comprehension focused on narrative texts, especially historical texts that are easy to comprehend. The content usually includes the setting, actions, events, and goals which are very familiar in our daily life (e.g. Bower, Black, & Turner, 1979; Mandler & Johnson, 1977; Rumelhart, 1975), and actions and events are described in temporal order. In addition, in terms of text structure, these historical texts do not have sophisticated literary forms (usually cause-effect style) so that readers are easy to use their schema to predict what will happen next.

In contrast, scientific texts are far more complicated. Generally speaking, scientific text can be defined as the text that involves science, mathematics, engineering, and technology. There are academic textbooks, scientific journal articles, technical manuals, and information brochures for the public (Goldman & Bisanz, 2002; Graesser, Leon, & Otero, 2002). The material conveys new knowledge about science. The content of scientific texts is usually extremely complicated and hard to understand at a deep level. Most readers with little background knowledge or immature reading skill feel challenging reading scientific texts and easily give up learning. In addition, the text structure of scientific texts varies from text to text. The text structure may be cause/effect, compare/contrast, problem/solution, or descriptive style. Thus, it is necessary to conduct more studies on scientific texts in order to improve children's scientific learning.

Text Coherence and Text Comprehension

The quality of instructional texts has long been a concern to professionals in many areas of educational research and practice (Chall & Conard, 1991; Chambliss, 2002). Text coherence plays an important role for the process of text comprehension. *Text coherence* is usually defined as "the degree to which the concepts, ideas and relations in a text are explicit and interconnected" (Graesser, McNamara, & Louwerse, 2003; McNamara & Kintsch, 1996; O'Reilly & McNamara, 2007)." The writing found in textbooks is often loosely organized and incoherent and requires some domain-specific information and text structure that readers do not know (Chambliss, 1994). Beck, McKeown, & Gromoll (1989) found that many social studies texts usually present too much information with too little explanation, as well as loose connections among sentences or paragraphs. These disjointed and incoherent texts impede comprehension and force readers to form disconnected and incoherent representation of text.

Many studies have shown that readers' comprehension can be promoted by using specific principles to improve text coherence (Beck, McKeown, Sinatra, & Loxterman, 1991; Britton & Gulgoz, 1991; Lehman & Schraw, 2002; Linderholm et al., 2000; Vidal-Abarca, Martinez, & Gilabert, 2000). Therefore, another question has been raised: is there any way that we can rewrite or re-organize the text and make it more comprehensible? If there are some principles that can be adopted, is it feasible to use them in order to improve young students' comprehension?

Reading Ability and Text Comprehension

Reading ability also has a large impact on text comprehension; it is generally expected to be related to how readers process and learn from text. In order to comprehend a text, readers need to develop some basic skills such as letter identification, word decoding and inference skill, and they also require sufficient domain knowledge. Skilled readers comprehend more information from text because they have better word representation (e.g., Perfetti, 1985), make more accurate inferences (e.g., Oakhill, 1993; Oakhill & Yuill, 1996), and use more strategies (e.g., Baker & Brown, 1984; Magliano & Millis, 2004). In addition, readers who have more background knowledge about the text understand better and learn more from text (e.g., Brandsford & Johnson, 1972; Shapiro, 2004). However, young readers sometimes do not develop proficient skills and do not possess sufficient knowledge to process a text, so that they are unable to retrieve the meaning from text. The problem is more serious when these less-skilled young readers encounter unfamiliar concepts in scientific texts. Thus, we want to see how readers with different levels of ability comprehend difficult scientific texts.

The Purposes of This Study

There are three purposes to this study. First, we want to know whether revision principles that have been successfully used on texts for advanced readers can also be adopted for revising young readers' texts. Several studies (e.g., Britton & Gulgoz, 1991; Linderholm et al, 2000; McNamara & Kintsch, 1996; Vidal-Abarca et al., 2000) have shown that rewriting a text and making it coherent can benefit advanced readers' comprehension. Readers who read a revised text have better comprehension than those who read an original text. Specifically, these readers have a better memory and an accurate mental representation of the text. These studies have shown that using systematic revision principles can successfully improve a text and benefit readers' comprehension.

However, most researchers have been more interested in advanced readers in high school (e. g., Boscolo & Mason, 2003; Vidal-Abarca et al., 2000; McNamara, Kintsch, Songer, & Kintsch, 1996; Gilabert, Martinez, & Vidal-Abraca, 2005), or college (e.g., Britton & Gulgoz, 1991; Linderholm et al., 2000; McNamara & Kintsch, 1996; O'Reilly & McNamara, 2007) than in elementary school. Only two studies (i.e., Beck et al., 1991; McNamara et al., 1996) have been conducted with students at the fourth to sixth grade level. We examined whether the revision principles have an impact on young readers' comprehension.

Second, the most commonly used domain for revision studies has been history (e.g. Beck et al.,1991; Britton & Gulgoz, 1991; Linderholm et al., 2000; Vidal-Abarca et al., 2000). Very few studies (e.g. Boscolo & Mason, 2003; McNamara et al., 1996; O'Reilly & McNamara, 2007) have focused on the scientific domain. We want to investigate whether the principles used in history texts can be also applied to scientific texts. Scientific texts often involve more domain-specific knowledge and are much harder to comprehend than texts whose content comes from other domains.

Third, we looked at the interaction of text coherence and reading ability. Linderholm et al. (2000) examined the interaction effects of text coherence, text difficulty and reading ability. Recall and comprehension measures indicated that both more- and less-skilled college students benefited from revision, but only in a difficult text condition. More- and less-skilled readers were roughly equivalent both on the original text and on its revised version when the texts were easy. The present study followed up on Linderholm et al.'s findings, examining text coherence and reading ability in young children. The reading level of the experimental materials in this study was anchored at a higher grade level (i.e., seventh grade) than the grade level of the participants (i.e. sixth grade). Two scientific texts of different length and concept complexity were used.

The following section reviews the processes involved in reading comprehension, as well as factors that influence comprehension, such as text coherence and reading ability. Studies focused on the improvement of text will be reviewed as well.

The Process of Reading Comprehension

There is general acceptance in the field of reading that reading is a complex, interactive process (e.g., Kintsch, 1998; Just & Carpenter, 1987). Readers construct meaning by combining textual information with their background knowledge to create a mental representation of the text. At each point during reading, the reader tries to make sense of the information explicitly stated in the current sentence by connecting it with associated concepts in background knowledge and other related concepts from preceding sentences (Kintsch, 1988; Kintsch & van Dijk, 1978; van den Broek, 1990). The connection of information between sentences and the integration of relevant background knowledge with the textual information are generated by various types of inferences. Take the following sentences as an example,

(1) The waitress dropped the cup.

(2) The girl's finger bled.

To understand these two sentences, the reader has to comprehend that *the waitress* is referred to as *the girl*. This is called "*referential inference*" (Kintsch, 1998). In the same sense, background knowledge is also necessary: If a reader cannot make a *causal inference* to connect sentence (1) and (2), he or she may fail to understand why the girl's finger bled. Most of the time, authentic texts are not as simple as the example mentioned above. Sometimes inferences need to be generated (e.g., a bridge inference) because related concepts for understanding the text are spread across distant sentences or across several paragraphs. Readers must hold these concepts in their working memory and carry them over several sentences in order to link related concepts. Once readers are satisfied with their understanding of the sentence, they will move on to next sentence until they reach the end of the text.

The Levels of Text Comprehension

From a theoretical point of view, the common sense notion of *comprehension* is not sufficient to explain to what degree a reader understands a text. For example, it is very obvious that recognizing a word is different from recalling story details and interpreting a story theme. In text comprehension theory, three levels of comprehension have been identified (van Dijk & Kintsch, 1983).

The first level of text comprehension is the *surface code*, which represents the exact wordings and phrases in the text. Decoding and recognizing syntax of clauses can be considered as part of this level of text comprehension. The second level of text comprehension is the *textbase*, which contains explicit text propositions that preserve the meaning, but not the exact wording and phrases of the text. To construct the textbase, readers need syntactic and semantic knowledge. Sometimes the textbase includes a few inferences that establish local text coherence. One of the obvious examples of textbase comprehension is text recall. Textbase comprehension is usually considered a shallow level of comprehension.

The third level is the *situation model*; this is the content or microworld of the text, which corresponds to a deeper level of comprehension (Graesser, Millis, & Zwaan, 1997; Kintsch, 1994). Texts usually describe a real or fictional situation in the world. Readers have to integrate the textbase information with their own background knowledge in order to construct a situation model. The integration of textual information and background knowledge usually require efforts such as bridge inferences, elaboration inferences, and problem-solving skills, so that a useful and coherent situation model can be constructed. Because the process of comprehending the situation model is more demanding than the other two levels of comprehension (i. e., surface code and textbase), the situation model is considered to be a deep level of comprehension or *learning from text*. Building up an accurate textbase and situation model is the ultimate goal of reading comprehension.

It is not always easy for a reader to form a textbase and situation model. Two major sources influence readers' comprehension (Britton, Woodward, & Binkley, 1993; van den Broek & Kremer, 2000) – reading ability and text factors.

Reading Ability Affects Text Comprehension

Reading ability has been shown to have a large impact on text comprehension. Reading ability can be defined as the cognitive capacities (e.g., attention, memory, and inference skills) and knowledge (e.g., vocabulary, domain knowledge, and reading strategies) for comprehending a text (Britton, Gulgoz, & Glynn, 1993; RAND, 2002; van den Broek & Kremer, 2000). Because readers differ in their cognitive capacities and knowledge, readers may process, interpret, and recall the same text in very different ways (van den Broek, Young, Tzeng, & Linderholm, 1999). For example, high-ability readers acquire more information from text because they have better word-decoding skills (Perfetti, 1985). Readers who know how to use strategies during reading can comprehend a text better than those who do not use any (Baker & Brown, 1984; Magliano & Millis, 2004; Oakhill & Yuill, 1996). Skilled readers have been shown to have better inference skills and can generate more accurate inferences than less-skilled readers (Oakhill, 1984; Oakhill, 1993). People who have high reading ability typically demonstrate that they can consistently process text successfully by performance on some form of assessment, such as reading a passage and answering comprehension questions. People who have high reading ability generally display superior academic performance in many domains.

However, possessing good reading skill does not always lead to successful comprehension on a deep level. Reading ability is comprised of two central components, reading skill and background knowledge, according to Kintsch's (1988) Construction-Integration model. Readers have to retrieve their background knowledge from memory and use it to make various types of inferences for constructing a coherent mental representation (McNamara et al., 1996; Graesser, Singer, & Trabrasso, 1994; Magliano, Trabasso, & Graesser, 1999). Background knowledge affects text comprehension; this was widely explored in the 1970s and 1980s (Anderson & Pearson 1984). Good readers usually have rich and densely interconnected knowledge stored in memory, so that they can retrieve requisite information easily and immediately for comprehension (Ericsson & Kintsch, 1995). Poor readers may fail to understand implicit or incoherent sentences because they cannot establish essential inferences to connect the information in the text with relevant background knowledge.

In sum, reading ability is an influential factor that affects reading comprehension. Individual difference in reading skills and background knowledge may generate different text comprehension even when reading the same text. High ability readers usually have more advantage than low ability readers in constructing a useful mental representation of a text.

Text Factors Influence Text Comprehension

There are two major text factors that influence text comprehension— text content and text structure. Text content includes facts and concepts, i.e. the information that the author wants to convey to readers. Familiarity of content (Bartlett, 1932; Bransford & Johnson, 1972) and number of referential/causal connections (van den Broek et al., 1999) affect the difficulty of the text. Readers can easily understand the text with familiar content because they can use their pre-existing knowledge to assimilate information from the text. That is, they can use their schemas to bridge the gaps when there is something that the author did not express clearly. Similarly, when the text is familiar, it is much easier to make fewer inferences to connect information that is spread across different sentences or paragraphs.

Text structure also influences comprehension. Sometimes the same information can be conveyed in very different ways, some of which are more user-friendly than others. A user-friendly text, which means a text with a well-written structure, usually reduces the cognitive load and the need for inference-making during reading. A number of studies have shown that improving text structure can benefit readers' comprehension (e.g., Cook & Mayer, 1988; Meyer, Brandt, & Bluth, 1980; Lorch & Lorch, 1996).

Coherence and Text Comprehension

Recently, more and more evidence has shown that text coherence plays a key role in comprehension (Britton & Gulgoz, 1991; McNamara et al., 1996; Linderholm et al., 2000; O'Reilly & McNamara, 2007; Sanders & Noordman, 2000; Vidal-Abarca et al., 2000). The notion of text coherence can be defined as "how well the parts of the text stick together (Meyer, 2003, p. 208)" or "the degree to which text propositions are interconnected in the reader's mental representation of the text (McNamara & Kintsch, 1996, p. 254)." A text that helps the reader to form a coherent mental representation is called a coherent text.

As discussed above, reading comprehension is constructed on the basis of integration of written information and readers' background knowledge. A coherent text can provide a user-friendly structure that allows readers to identify the relationships between ideas in the texts and make necessary connections among them. Graesser et al. (2003) asserted that a text is determined to be coherent when the ideas hang together in a meaningful and organized manner. With a coherent text, readers may not need to make a lot of inferences in order to capture the relation among ideas. At the other end of the continuum, a non-coherent text has many coherence breaks, and readers require background knowledge to fix them. In order to comprehend such a text, readers need to make additional efforts and to make various types of inferences to repair the breaks. Britton et al. (1993, p. 20) stressed that "if a text calls for the reader to do a lot of extra mental work to create a good mental representation, many readers will fail to do the work or do it wrong and so their representation will be poor."

The coherence relations of a text are at two levels, the local and the global. Local coherence is achieved when a sentence can be connected to previous sentences in working memory. Global coherence is achieved when a sentence can be connected to main ideas of other paragraphs, that is, to an idea that is no longer maintained in working memory. Readers usually attempt to sustain coherence on both the local and the global level during reading (see Graesser et al., 1997; Graesser et al., 1994). Good readers will detect the inconsistencies in the text when there is contradiction at the local and global level. For example, a passage that starts out by describing the ways to prevent global warming but ends up promoting increasing gasoline consumption is contradictory. Normally, an engaged reader would not be able to achieve global coherence of that text because of the contradiction. Similarly, readers will notice incoherence at local level. For instance, "The waitress dropped a cup. The girl's finger bled badly." Because there is no explicit statement that the girl mentioned in the second sentence is the waitress and that the girl's finger was hurt by the broken cup, the reader has to generate referential and causal inferences to bridge the local coherence break. Thus, it is essential that writers provide sufficient devices in the text to build up the coherence relations, especially in texts designed for people with limited reading ability.

In sum, a coherent text is better organized than a less-coherent text, and it is easier to comprehend. Readers are more likely to construct a meaningful and useful mental representation of such a text and achieve better comprehension of both the textbase and the situation model.

Different Text Revision Approaches can Improve Comprehension

Many research studies have focused on improving text quality to enhance students' comprehension and learning. Two approaches to improve text quality, in order to make texts more comprehensible, are described here.

Traditional Approaches of Text Revision. Readability has been an important concern for cognitive psychologists and educators for many years. Researchers have attempted to improve text comprehension in a variety of ways. Several studies successfully have shown that texts that were rewritten by professional writers could improve readers' comprehension (Britton et al., 1993; Britton, Van Dusen, Gulgoz, & Glynn, 1989). Some researchers have revised text by using readability formulas that assess text difficulty by calculating word frequency and sentence length; they rewrote the text, using different vocabulary and shorter sentences, to adjust the text difficulty (Davison, 1984; Duffy et al., 1989). Others have used writing experts' intuition as a basis for text revision (Britton et al., 1989; Graves et al., 1991).

However, these approaches have been criticized. It is obvious that readability formulas do not account for complex linguistic text structure. A readability formula cannot reliably provide guidelines for revising text (Kintsch & Vipond, 1979). Similarly, writing experts' suggestions based on their intuition are ambiguous and hard to follow (Sawyer, 1991).

A Cognitive Theory of Text Revision. Cognitive theory sees reading as a complex process, one that depends on reader characteristics and text properties (Dole, Duffy, Roehler, & Pearson, 1991). Because of their dissatisfaction with readability formulas and experts' intuitions, cognitive scientists have worked to revise text via systematic principles from cognitive theory.

For example, Beck and her colleagues began to identify the problems in text and to revise them according to cognitive theory by focusing on how reader characteristics and text properties interact (Beck et al., 1991). They chose four short and problematic passages about American Revolution from a fifth-grade social studies textbook and revised them according to several rules, such as "clarifying," "elaborating," "explaining and providing motivation for important information" and "making connections explicit." Forty-five fourth- and 40 fifth- graders were assigned to read either original or revised passages. The results showed that participants who read the revised texts recalled more material and answered more questions correctly than participants who read the original texts. Similar results were also found in their qualitative analysis.

In another study, Britton and Gulgoz (1991) adopted Kintsch and van Dijk (1978) computational psychological model to improve instructional texts. They developed three concrete principles for revising text, which were “argument overlap,” “given-new,” and “making concepts explicit.” They repaired coherence breaks in an ambiguous history text about Vietnam War and produced a principled version using the three principles. They also produced a heuristic version (by adding subtitles, highlighting, etc.). One hundred seventy undergraduates were tested on free recall, factual questions and inference questions. The results showed that participants who read the principled version or the heuristic version performed better on the free recall and the inference questions than those who the read original version. As they had predicted, there was no difference among the 3 groups on the multiple-choice factual questions because participants only had to recognize the answer from multiple-choice questions. In addition, the knowledge structure of the author of the original text and of seven subject-matter experts was measured by calculating the statistical distance among concepts presented in the text. Their knowledge structure was compared to the knowledge structure of the participants who read the principled version. The result showed that those participants, the author of the original text, and the seven experts shared a similar pattern of knowledge structure. It was concluded that the revision aided comprehension.

Another study, conducted by Vidal-Abarca et al. (2000), was also derived from Kintsch’s theory and was further motivated by narrative comprehension theory (Trabasso, Secco, & van den Broek, 1984). The purpose of the study was to compare two approaches for improving instructional text. The authors created three versions of a Russian revolution text for eighth graders. The first version was revised by reducing the reader’s inferential activity by increasing argument-overlap. In the second version, additional information was inserted to trigger causal inferences. The third version was a combination of the first two. The authors predicted that argument-overlap changes would not produce positive effects at deep level of understanding, but that the causal constructionist changes would affect this level. On the other hand, the argument-overlap changes would benefit text recall, but causal constructionist change would not. The results showed that students who read the causal constructionist version performed better on inferential questions than those who read the argument-overlap version. However, there was no significant difference between the two versions on the recall measure.

Several conclusions can be drawn from these studies. First, text comprehension can be improved by providing a well-written version of a text. There is solid evidence that historical texts can be improved by the application of several concrete principles and that readers can benefit from such revision. Second, the effects on different comprehension measures varied when different approaches to revision were adopted. It appears that textbase (recall) measures benefit from the application of Kintsch’s argument-overlap principle, whereas situation model (inference questions) measures benefit from causal-relation repair. Third, readers of different ages show improvement in their text comprehension after text revision. Studies have shown that text comprehension is superior at the fourth, fifth, eighth grade and college level when students read a more coherent version of the text.

Effects on Comprehension as Function of the Interaction of Text Coherence and Reading Ability

Comprehension as a Function of Text Coherence and Background Knowledge. Some researchers have been interested in the interaction between text and reader. Their studies examined how text coherence interacts with reader ability, including background knowledge (Boscolo & Mason, 2003; Gilabert et al., 2005; McNamara et al., 1996; McNamara & Kintsch, 1996) and reading skill (Linderholm et al. 2000; O’Reilly & McNamara, 2007).

McNamara et al. (1996) revised a text concerning heart disease, writing a maximum coherent and a minimum coherent version, to investigate the interaction of text coherence and background knowledge. The authors found that readers who have little knowledge about the text content answer more inference questions correctly when reading highly coherent text, whereas high knowledge readers answer more inference questions correctly when reading low coherent text. However, this interaction effect did not show up on a recall (textbase) measure. McNamara et al. called this counterintuitive result a "reverse cohesion effect" (O'Reilly & McNamara, 2007) and explained that it happened because less-coherent text made high-knowledge readers actively process at a deep level of comprehension. High-coherent text, on the other hand, led to passive processing.

Other studies did not show such an interaction between text coherence and background knowledge. For example, McKeown, Beck, Sinatra, and Loxterman (1992) found main effects of both text coherence and background knowledge, but no interaction. Similarly, Gilabert et al. (2005) found that their explicit version of texts improved the performance of both low and high knowledge readers, but again there was no interaction between text coherence and background knowledge. The same finding was also reported in Boscolo and Mason's (2003) study.

However, two recent studies present new findings concerning the interaction between text coherence and background knowledge. Kamalski, Sanders and Lentz (2008) manipulated two types of text, informative and persuasive, to investigate the interaction between text coherence and background knowledge. In their first experiment, they found an interaction effect such that low knowledge readers benefited from reading a coherent text, whereas high knowledge readers benefited equally after reading either a coherent or a less-coherent version. The *reverse effect* as found by McNamara et al. (1996) was found only in the third experiment that they performed, in which they improved their methodology by using movie clips to control background knowledge and by administering a sorting task to measure comprehension. However, the effect was limited to informative text only.

O'Reilly and McNamara (2007) investigated whether comprehension skill affects the interaction between text coherence and background knowledge. Participants' comprehension skill was measured by a standardized reading comprehension test (i.e., Nelson-Denny test) and a questionnaire that was designed to measure knowledge of metacognitive reading strategies. The results indicated that skilled readers with high background knowledge benefited from reading a highly coherent text. The "reverse cohesion effect" was restricted to less-skilled readers with high background knowledge.

Comprehension as a Function of Text Coherence and Reading Skill. A study by Voss and Silfies (1996) found that the effect of text coherence depends on reading skill as well as on background knowledge. They gave college students two versions of fictional history texts to read and used correlation analysis to examine the relation among text coherence, reading skill, and background knowledge. Reading skill was measured by a *reading-comprehension set*, which included Nelson-Danny reading comprehension test, reading rate, and GPA. Background knowledge was determined by a *history-knowledge set*, which included a history-knowledge test, interest in history and number of relevant courses taken. The results showed that reading skill was correlated with performance on the high coherent text, whereas background knowledge was correlated with performance on the low coherent text.

In contrast to Voss and Silfies' (1996) results, Linderholm et al. (2000) found that both skilled and less-skilled readers benefit from reading high coherent text on recall and comprehension measures. Linderholm et al. examined the interaction effect of text coherence, text difficulty and reading ability. The revision principles they used for revising difficult and easy causal texts were derived from narrative comprehension theory (Trabasso et al., 1984; van den Broek, 1994); the principles were *adjusting temporal order*, *making goals explicit*, and *repairing coherence breaks*. More-skilled and less-skilled readers were differentiated by a median split of their scores on a reading comprehension test. Results indicated that both more- and less-skilled college students benefited from the revision, but only in the difficult text condition. The recall and comprehension measures of more- and less-skilled readers were roughly equivalent on the easy text condition.

In sum, it is not clear how text coherence and reading ability interact. Some studies have shown that text coherence interacts with background knowledge, and that only low knowledge readers benefit from text coherence (Kamalski et al., 2008; McNamara et al., 1996; McNamara & Kintsch, 1996). Other studies have found no interaction (Boscolo & Mason, 2003; Gilabert et al., 2005; McKeown et al., 1992), that is, that the text coherence benefits all readers equally (Linderholm et al., 2000).

There are three questions that have not been completely answered by previous studies. First, do young children benefit as much as older readers do from text revision? Previous studies have shown that making a text coherent via text revision can improve readers' comprehension at the high school or college level, but there is little evidence about the effects of text revision for younger children. There are many differences between advanced readers and young readers that might lead to a different answer for young readers.

Second, can the principles that have been used in history texts also be applied to scientific texts? Most of the revision studies used short, problematic history texts. There are differences between history texts and scientific texts. For example, temporal order, goals of the protagonist, and causal relations characterize and affect the comprehension of history text, whereas argument repetition and concept complexity affect comprehension of scientific texts. We want to examine whether the principles that were used in revising history texts can be applied to authentic scientific texts.

Third, the findings of previous studies on the interaction of text coherence and reading ability are not consistent. The *reverse cohesion effec*t, that only readers with low background knowledge benefit from coherent texts were found by McNamara (McNamara et al., 1996; McNamara & Kintsch, 1996), but has not been found in other studies. For example, Boscolo & Mason (2003) and McKeown et al. (1992) found no interaction between background knowledge. Also Linderholm et al. (2000) found no interaction between reading skill and text coherence.

The Study

In order to answer the preceding questions, this study investigated whether revision principles used in previous studies can be successfully applied to revise children's scientific text, and whether children's comprehension can be improved by text revision. Four principles, (1) argument-overlap, (2) making concepts explicit, (3) adding connectives, and (4) inserting macro-structure, were used to rewrite two scientific texts from a seventh-grade textbook.

In addition, we investigated the effects of text revision on different levels of comprehension (i.e., shallow and deep comprehension). Participants' comprehension was measured by two different tasks: a free recall task and a comprehension task. In the free recall task, participants were encouraged to write down as much text information as they could remember after they read a text. The recall protocols reflected how much information that participants learned from the texts. The comprehension task consisted of 16 short answer questions, which probed participants' shallow comprehension (questions concerning the textbase) and deep comprehension (inference questions).

This study also examined whether text coherence interacts with reading ability. When children read difficult texts, does text coherence benefit high-ability and low-ability children's comprehension equally, or does it benefit only one end of the reading ability continuum? In other words, if reading revised texts improves all readers' comprehension, there is no interaction between text coherence and reading ability. On the other hand, if only high ability or only low ability children improve their comprehension by reading revised texts, text coherence does interact with reading ability.

Method

Participants

Four regular intact classes (100 six-grade students) were recruited from a public school in Taipei City, Taiwan. Most of the participants came from middle-class families and used Mandarin as their first language. Nine of the students were diagnosed as having learning and reading difficulties; they participated in the study, but their data were eliminated from the analysis, and the final sample consisted of 91 students. All participants received a pencil and an eraser as remuneration for three 45-minute sessions.

Material

Original Text. Two scientific texts were chosen from a seventh-grade biological textbook (Kang Hsuan, 2006). One of the texts was entitled “What is diabetes?” and the other text was entitled “The feeling of pain.” The length of the *diabetes* and *pain* texts was 548 and 348 Chinese characters, respectively. According to Ging’s (1994) Chinese readability scale, the readability level for the *diabetes* text was at the 6.68 grade level and for the *pain* text, the 5.44 grade level. In terms of text structure both texts can be classified as having a descriptive format. Each text was shown on one page, double spaced.

Two texts were chosen (instead only one) for two reasons. First, because of children’s limited cognitive and attention capacity, these participants were not able to read a long text all at once. Giving one short text at a time, to reduce children’s cognitive load, is a more effective way to measure these children’s comprehension. Second, two texts of different length and conceptual density may help to determine the impact of text difficulty. Although both texts were adopted from 7th-grade textbook, the diabetes text was harder than the pain text. We can compare the effects of text cohesion and reading ability on the two texts in order to see the influence of text difficulty.

Revised Text. The two scientific texts were revised according to the following principles adapted from previous studies (e.g., Beck et al., 1991; Britton & Gulgoz, 1991; Linderholm et al., 2000; McNamara et al., 1996). Some examples were listed at Appendix A.

1. *Provide the argument-overlap*: Whenever a particular concept appeared in the text, the same term was used for it. Pronouns were replaced with noun phrases when the referent was potentially ambiguous. In addition, the relations among sentences were revised to improve local coherence. Namely, each sentence and its preceding sentence had a closely conceptual connection, after revision. By doing this, a mental representation of the textbase would be easier to build up for future retrieval.
2. *Make implicit concepts explicit*: Some ambiguous sentences were rewritten in direct and explicit format, to reduce the need for inference-making and to make it easier to build up a useful textbase representation.
3. *Change the order of sentences and paragraphs*: The order of some sentences and paragraphs was changed, to achieve a better semantic and global coherence.
4. *Add macro-structure to the text*: Topic sentences and subheads were added to the text to improve global coherence. These changes signaled the importance of concepts in the text.

After revising, the length of the diabetes text increased from 548 to 730 Chinese characters, and the pain text increased from 348 to 491 Chinese characters. The readability of the revised version of the *diabetic* text was higher (7.04 grade level) than that of the original version (6.68 grade level), and the readability of the revised version of the *pain* text was slightly higher (5.63 grade level) than the readability to the original version (5.44 grade level).

To ensure that the revised versions were more coherent than the original ones, ten middle-school science teachers were asked to rate the readability of both versions of the texts according to a nine-item Likert-scale questionnaire that was rewritten from Lehman and Schraw's (2002) study. The teachers agreed that the revised texts were more coherent than the original ones on both local and global level, $t(9) = 2.37$, $p < .05$, $d = .5$ for the diabetes text and $t(9) = 2.71$, $p < .05$, $d = 1.14$ for the pain text.

Design and procedure

The design was a two by two (original text vs. revised text and high ability vs. low ability) factorial design with background knowledge as a covariate. The dependent variables were a free-recall measure and a comprehension measure (including textbase and inference questions). Participants recalled the texts and answered the posttest questions immediately after they read the texts.

The experiment was conducted in the students' classroom during three weekly sessions. In the first session, all participants were administered *the Chinese Reading Difficulty Diagnostic Test* and *the Chinese Reading Comprehension Test*. This session took approximately 50 minutes.

In the second session (the second week), all participants were given a brief instruction about how to perform the tasks. They were given a booklet, which included a sample text, a filler task, a free-recall sheet and three short-answer questions. The researcher led participants through every experimental task and ensured that all participants understood how to perform each of them. After this instruction, participants were administered *the background knowledge assessment*. This session took about 50 minutes.

In the third session (the third week), participants were divided into high-ability and the low-ability groups according to a median split of their scores of *the Chinese Reading Comprehension Test*. Students in each ability group were randomly assigned to read either the original or the revised texts without time limitation. The sequence of the experimental tasks was as follows: (a) text reading, (b) filler task, (c) text recall, (d) posttest questions. Students finished all the tasks in 40 minutes to one hour. Then participants repeated the four experimental tasks one day later for the second text.

Measures

Reading Difficulty Diagnostic Test. In the first session, *the Chinese Reading Difficulty Diagnostic Test* (Ko, 1999) was administered to all participants (i.e., 100 students). This test consisted of 20 multiple-choice questions that examined 3rd to 6th graders' basic Chinese syntax and sentence understanding. The Cronbach α values range from .75 to .86. Students whose scores were lower than 15 were considered as having reading disabilities (i.e., 9 participants), and their data were eliminated from analysis. Thus the final sample consisted of 91 students.

Reading Comprehension Test. The Chinese Reading Comprehension Test (Su & Lin, 1992) was developed to assess passage comprehension. It included 5 short narrative and 5 expository passages, followed by 5 multiple-choice questions for each passage (total $n = 50$), based on Gagné's reading comprehension model. The Cronbach α reliability was .82. This test was used for distinguishing high reading ability ($M = 35.35$, $SD = 3.68$) from low reading ability children ($M = 23.41$, $SD = 4.19$) by using the median score (i.e., 29 points). High-ability readers had significantly higher scores on the reading comprehension test than did low-ability readers, $F(1, 89) = 207.89$, $MSE = 3174.95$, $p < .01$, $\eta^2 = .7$.

Background Knowledge Assessment. This assessment was developed by the researcher. It included 15 true-and –false questions and 15 multiple-choice questions, to examine pre-existing background knowledge differences, between the groups. All 30 questions were related to health and body function.

Examples of these questions are *“A normal human’s body temperature usually ranges from 36 to 37 degree centigrade. True or False.”* Or *“The human nervous system includes the brain, the spinal cord and the ________. (1) nerves (2) skeleton (3) blood (4) endocrine”* All questions were finished in 15 minutes.

Filler Task. The filler task consisted of five addition and five multiplication questions. This task was administered to participants after they finished reading each experimental text, in order to prevent them from rehearsing. This task was finished in 3 minutes.

Free recall. Participants were asked to “write down as much as you can remember about the text” and given enough time to write down what they remembered. The recall protocols were scored against a list of idea units from the original text. Two raters scored the recall protocols independently. The inter-rater reliability was $r = .94$, $p < .01$, for one class out of the four, for the diabetes text, and $r = .95$, $p < .01$, for another one of the four classes, for the pain text. Any inconsistent results were solved by discussion.

Posttest Questions. The posttest questions consisted of 9 short-answer questions for the *diabetes* text and 7 short-answer questions for the *pain* text, which were developed by the researcher. These questions were classified into two different types: (a) textbase questions that examined children’s memory of textual information in the original text (i.e., shallow comprehension), (b) inference questions that required some types of inference-making and reasoning (i.e., deep comprehension). Examples of textbase and inference questions are listed below:

“Write down three obvious symptoms of diabetes.” (Textbase question)

“If a diabetic stops eating sugar, will his diabetes be cured?” (Inference question)

“Write down the functions of pain.” (Textbase question)

“John scalded his hand. He felt less pain after a while. Why did this happen?” (Inference question)

There were 5 textbase questions and 4 inference questions for the diabetes text, and 3 textbase questions and 4 inference questions for the pain text.

Scoring of Posttest Questions. A scoring template was established for each posttest question. Because the level of difficulty was such that the texts and questions would be challenging for participants of this age level, their responses were scored according to a relatively lenient criterion. In other words, the scorer gave partial credit to participants whose answers were incomplete or ambiguous. The maximum score on the “diabetes” posttest was 21 and the maximum score of the “pain” posttest was 16. To examine the different levels of comprehension, the two types of posttest questions (i.e., textbase questions and inference questions) were scored separately, which produced a shallow comprehension score (based on the textbase questions) and a deep comprehension score (based on the inference questions). Two raters scored the posttest questions independently. The inter-rater reliability were $r = .96$, $p < .01$, for one class out of the four, for the diabetes text, and $r = .93$, $p < .01$, for another one of the four classes, for the pain text. Any inconsistent results were solved by discussion.

Results

General Descriptive Statistics

Table 1 presents the means and standard deviation as well as the minimum and maximum scores for each of the individual difference measures and the dependent measures. Table 2 presents correlation between the measures. The correlation between the background knowledge assessment and the reading comprehension test indicate that the background knowledge measure was highly correlated with the reading comprehension measure ($r = .43$, $p < .01$). This result is to be expected because performance on a comprehension test involves knowledge use. However, the background knowledge measure correlated with only one dependent measure, the free recall of the diabetes text, $r = .36$, $p < .01$. These non-significant results were also expected because the background knowledge assessment measured general science knowledge and did not target the content of the two experimental texts. In addition, the correlations between the reading comprehension test and the dependent measures showed that reading ability significantly correlated with all dependent measures. The dependent measures were also correlated among themselves.

Moreover, Table 2 also presents the construct validity of dependent measures in terms of Multitrait-Multimethod approach. For convergent validity, there were high correlations between two recall measures (i.e., $r = .72$) and between the recall and textbase measure (e.g., correlation between diabetes recall and diabetes textbase, $r = .65$). On the other hand, Table 2 also shows discriminant validity of posttest measures. There were low correlations between the recall and inference measures because these measures accessed different constructs in reading. For example, the correlation between pain recall and diabetes inference was low ($r = .39$). In sum, the results indicate that all posttest measures serve as valid tools for access different levels of reading comprehension.

Table 1 *Means and standard deviations as well as the minimum and maximum scores that students received on all measures*

Measure	*Mean*	*SD*	*Minimum*	*Maximum*
Pretest measures				
Background knowledge assessment	18.53	3.36	9	29
Reading comprehension test	30.23	7.10	15	44
Posttest measures				
Diabetes recall	.27	.12	.02	.53
Pain recall	.43	.24	0	.94
Diabetes textbase	.60	.22	0	1.00
Diabetes inference	.45	.27	0	1.00
Pain textbase	.54	.28	0	1
Pain inference	.39	.25	0	.90

Note. All posttest measures are presented in proportion of correct scores.

Table 2 *Correlations among all measures*

	1	2	3	4	5	6	7
Pretest measures							
1. Background knowledge	--						
2. Reading comprehension	.43**	--					
Posttest measures							
3. Diabetes recall	.19	.27**	--				
4. Pain recall	.16	.36**	.72**	--			
5. Diabetes textbase	.36**	.43**	.65**	.54**	--		
6. Diabetes inference	.16	.22*	.54**	.39**	.57**	--	
7. Pain textbase	.19	.33**	.52**	.53**	.52**	.49**	--
8. Pain inference	.19	.37**	.45**	.50**	.52**	.47**	.63**

*$p < .05$， ** $p < .01$

Background Knowledge Assessment

Participants were divided into high-ability and low-ability groups and then randomly assigned to read either original texts or revised texts. Thus, there were four experimental conditions (i.e., low-ability and original text, low-ability and revised text, high-ability and original text, and high-ability and revised text). The means on the test of background knowledge for each condition were compared. The results showed that there was a significant difference among conditions, $F(3, 87) = 5.04$, $p < .01$, $\eta^2 = .15$. The group of high-ability participants who read original texts ($M = 20.32$, $SD = 3.02$) performed better than the other three groups ($M = 16.83$, $SD = 3.24$ for the low-ability, original text group; $M = 17.62$, $SD = 3.19$ for the low ability, revised text group; $M = 18.70$, $SD = 3.18$ for the high-ability, revised text group) on the background knowledge assessment. There was no significant difference among the other three groups. Thus, the scores of the background knowledge measure were used as a covariate in our analyses in order to adjust the posttest means.

The Multivariate Analysis

A multivariate analysis of covariance (MANCOVA) including the two between-subjects variables of text coherence (original version and revised version) and reading ability (low ability and high ability) was performed on the dependent measures, which included free recall, textbase questions, inference questions for both the diabetes and the pain text (i.e., a total of 6 dependent measures). The scores on the background knowledge assessment served as a covariate.

The MANCOVA revealed that there was a significant main effect of text coherence, $F(6, 75) = 4.34$, $p < .01$, $\eta^2 = .258$. There was also a main effect on reading ability, $F(6, 75) = 2.38$, $p < .05$, $\eta^2 = .160$. There was marginal significant interaction between text coherence and reading ability, $F(6, 75) = 2.07$, $p = .067$. The result is shown in Table 3.

Table 3 *Multivariate analysis of covariance for free recall, posttest questions*

Source	$F_{(6,75)}$	p	η^2
Background knowledge	1.664	.142	.117
Text coherence (A)	4.343**	.001	.258
Reading ability (B)	2.388*	.036	.160
A × B	2.067	.067	.142

$^*p < .05$， $^{**}p < .01$

For a deeper analysis of the observed effects, separate analyses were then conducted for each of the three dependent measures for each text.

Free Recall

Participants' scores on the free recall test are expressed in proportion of correct idea units. The means and standard deviations for each text are shown in Table 4 (diabetes text) and Table 5 (pain text). Univariate analyses were performed on each text separately. An analysis of covariance (ANCOVA) of the results on the diabetes text revealed that there was a significant main effect of text coherence, $F(1, 80) = 4.30$, $MSE = .058$, $p < .05$, $\eta^2 = .05$. Participants who read the revised diabetes text ($M = .29$, $SD = .13$) recalled more idea units than those who read the original diabetes text ($M = .24$, $SD = .11$). However, there was no main effect of reading ability [F(1, 80) = 1.08, MSE = .02, p = .30], and there was no interaction between text coherence and reading ability [F(1, 80) = .05, MSE = .001, p = .82].

Table 4 *Free-recall performance (proportion correct) as a function of text coherence and reading ability for the diabetes text*

	Original version			Revised version			Total		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Reading ability									
Low ability	.22	.14	16	.26	.12	18	.24	.13	34
High ability	.26	.09	25	.31	.13	26	.28	.11	51
Total ability	.24	.11	41	.29	.13	44	.27	.12	85

An analysis of covariance of the results on the pain text revealed a significant main effect of reading ability, F(1, 80) = 9.20, MSE = .47, p < .01, η^2 = .10. High ability participants (M = .50, SD = .23) recalled more idea units than low ability participants (M = .33, SD = .23). However, there was no significant main effect of text coherence [F(1, 80) = 3.17, MSE = .16, p = .08], and no interaction between text coherence and reading ability [F(1, 80) = 1.14, MSE = .06, p = .29].

Table 5 *Free-recall performance (proportion correct) as a function of text coherence and reading ability for the pain text*

	Original version			Revised version			Total		
	M	*SD*	*N*	*M*	*SD*	*n*	*M*	*SD*	*n*
Reading ability									
Low ability	.26	.18	16	.40	.25	18	.33	.23	34
High ability	.49	.24	25	.52	.21	26	.50	.23	51
Total ability	.40	.25	41	.47	.23	44	.43	.24	85

In sum, there was a tendency for participants who read the coherent (i.e., revised version) texts to recall more idea units than those who read the less coherent texts. The benefit of text coherence was reliable on the diabetes text although not on the pain text. The significant effect on the diabetes text supports previous studies (Beck et al., 1991; Britton & Gulgoz, 1991; Gilabert et al., 2005; Boscolo & Mason, 2003), which showed that coherent texts improve readers' memory for text. However, the non-significant result on the pain text, which indicated that text memory was not improved by reading more coherent text, is consistent with Vidal-Abarca et al.'s (2000) and Liderholm et al.'s (2000) studies.

In addition, high-ability readers performed better than low-ability readers on the recall measure only on the pain text. However, there was no interaction between text coherence and reading ability for either text. This non-significant result supports Liderholm et al.'s (2000) studies, indicating that both low-and high-ability readers benefited equally from more coherent texts.

Posttest Questions

The posttest questions were divided into textbase questions and inference questions in order to investigate different levels of comprehension. All analyses were conducted on proportion of correct scores.

Posttest, Textbase Questions

For the results on textbase questions of the two texts, the means and standard deviations of the scores (proportion of correct scores) are listed in Table 6 (diabetes text) and Table 7 (pain text). An ANCOVA was conducted separately on each text. For the diabetes text, there was no effect of text coherence, $F(1, 80) = 2.29$, $MSE = 9.63$, $p = .13$. However, there was a significant effect of reading ability, $F(1, 80) = 4.51$, $MSE = 18.94$, $p < .05$, $\eta^2 = .05$. High ability participants ($M = .67$, $SD = .19$) performed better than low ability participants ($M = .54$, $SD = .20$) on the textbase questions. There was no interaction between text coherence and reading ability, $F(1, 80) = .004$, $p = .95$.

Table 6 *Performance on textbase questions as a function of text coherence and reading ability for the diabetes text*

	Original version			Revised version			Total		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Reading ability									
Low ability	.50	.17	16	.57	.23	18	.54	.20	34
High ability	.66	.18	25	.69	.20	26	.67	.19	51
Total ability	.60	.19	41	.64	.22	44	.62	.21	85

For the pain text, there was a significant main effect of text coherence, $F(1, 80) = 7.98$, $MSE = 16.69$, $p < .05$, $\eta^2 = .09$. Participants who read the revised pain text ($M = .64$, $SD = .25$) performed better than those who read the original pain text ($M = .49$, $SD = .25$).There was a also significant main effect of reading ability for the pain text, $F(1, 80) = 5.43$, $MSE = 11.62$, $p < .05$, $\eta^2 = .06$. High ability participants ($M = .64$, $SD = .24$) performed better than low ability participants ($M = .46$, $SD = .26$) on the textbase questions. No significant interaction between text coherence and reading ability was found for the pain text, $F(1, 80) = .006$, $p = .94$.

In sum, participants obtained higher scores on these textbase questions and thereby benefited from the coherent text. This advantage was significant for those who read the revised version of one of the texts, the pain text. This finding was consistent with previous studies (McNamara et al., 1996), which showed that text coherence facilitates readers' textbase comprehension. Additionally, high-ability participants significantly outperformed low ability participants on the textbase questions on both the diabetes and the pain texts. This result supported previous studies (e.g., Brown, 1982; Linderholm et al., 2000; Oakhill & Yuill, 1996; Perfetti, 1985; O'Reilly & McNamara, 2007). However, the interaction of text coherence and reading ability was not significant. The non-significant result was consistent with the results of Linderholm et al.'s (2000) study.

Table 7 *Performance on textbase questions as a function of text coherence and reading ability for the pain text*

	Original version			Revised version			Total		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Reading ability									
Low ability	.40	.27	16	.53	.23	16	.46	.26	32
High ability	.56	.22	22	.70	.25	26	.64	.24	48
Total ability	.49	.25	38	.64	.25	42	.57	.26	80

Posttest, Inference Questions

For the inference questions, the means and standard deviations are shown in Table 8 (diabetes text) and Table 9 (pain text). For the diabetes text (Table 8), there was significant effect of text coherence, $F(1, 80) = 7.51$, $MSE = 49.29$, $p < .01$, $\eta^2 = .09$. Participants who read the revised version ($M = .54$, $SD = .28$) outperformed those who read the original version ($M = .39$, $SD = .23$). However, there was no main effect of reading ability, $F(1, 80) = 1.81$, $MSE = 12.35$, $p = .17$ and no interaction between text coherence and reading ability, $F(1, 80) = .52$, $MSE = .34$, $p = .47$.

Table 8 *Performance on inference questions as a function of text coherence and reading ability for the diabetes text*

	Original version			Revised version			Total		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Reading ability									
Low ability	.34	.25	16	.46	.29	18	.40	.27	34
High ability	.42	.23	25	.60	.27	26	.50	.27	51
Total ability	.39	.23	41	.54	.28	44	.47	.27	85

For the pain text (Table 9), there was a significant interaction between text coherence and reading ability, $F(1, 80) = 6.93$, $MSE = 29.23$, $p < .05$, $\eta^2 = .08$. Low ability participants who read the revised version of the pain text ($M = .51$, $SD = .23$) answered more inference questions than those who read the original version ($M = .16$, $SD = .15$), whereas high ability participants who read the revised version ($M = .51$, $SD = .25$) did not perform better than those who read the original version ($M = .42$, $SD = .17$). In addition, there a significant main effect of text coherence, $F(1, 80) = 24.03$, $MSE = 102.98$, $p < .01$, $\eta^2 = .23$. Participants who read the revised version ($M = .51$, $SD = .24$) outperformed those who read the original version ($M = .32$, $SD = .20$) on the inference questions. There was also a significant main effect of reading ability, $F(1, 80) = 5.23$, $MSE = 22.05$, $p < .05$, $\eta^2 = .06$. High ability participants ($M = .46$, $SD = .22$) outperformed low ability participants ($M = .34$, $SD = .26$) on the inference questions when reading the pain text.

Table 9 *Performance on inference questions as a function of text coherence and reading ability for the pain text*

	Original version			Revised version			Total		
	M	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*	*n*
Reading ability									
Low ability	.16	.15	16	.51	.23	18	.34	.26	34
High ability	.42	.17	25	.51	.25	26	.46	.22	51
Total ability	.32	.20	41	.51	.24	44	.41	.24	85

In sum, the results showed that deep comprehension (as measured by the inference questions) was a function of the interaction of text coherence and reading ability. That is, low ability readers' deep comprehension (i.e., scores on the inference questions) was improved by reading the coherent text, whereas high ability readers' deep comprehension was not improved. This conclusion is based on the significant interaction effect found in the pain text. The results on the pain text indicated that it was the low ability participants who gained from the coherent version of the text.

Discussion

This study had three purposes. First, we examined whether revision principles that have been successfully used on texts for advanced readers can also be used for revising young readers' texts. Second, we investigated whether the principles used in history texts can be also applied to scientific texts. Third, we examined the interaction between text coherence and reading ability. Two authentic scientific texts were taken from a 7th-grade biology textbook and revised according to four revision principles. Ninety-one 6th-grade students from four regular intact classes were divided into low-ability and high-ability groups and randomly assigned to read either the original texts or the revised texts. Participants' comprehension was measured by free recall, questions focused on the textbase, and inference questions. Results indicated that the comprehension of young readers was improved when they read the coherent version of texts. High-ability readers performed better than low-ability readers. An interaction between text coherence and reading ability emerged on the inference questions for the pain text. That is, low-ability readers' deep comprehension (i.e., scores on the inference questions) was improved by reading the coherent text, whereas high ability readers' deep comprehension was not improved.

Comprehension as a Function of Text Coherence

Two main purposes of this study were to examine the effect of text coherence on (1) children's comprehension and (2) scientific texts. There were significant main effects of text coherence on most of the measures for both texts. In addition, the results clearly showed that scientific texts can be improved by the use of revision principles. The texts that were used in this study included incomplete descriptions and implicit concepts. It was not easy for students to understand and remember the content. By applying the revision principles (i.e., *providing argument-overlaps, making implicit concepts more explicit, changing the order of sentences and paragraphs, and adding macro-structures*), the text quality was improved and the texts became easier to understand. Children who read the revised version of texts performed significantly better than those who read the original version of the texts. The improvement of comprehension appeared not only at the shallow level (textbase questions) but also at the deep level (inference questions). These results provide evidence about how to revise children's scientific texts.

The results of this study expanded on previous studies (e.g., Beck et al., 1991; Britton & Gulgoz, 1991; Linderholm et al., 2000; McNamara et al., 1996; Vidal-Abarca et al., 2000) designed to improve the comprehension of historical texts by adults and older students.

Comprehension as a Function of Reading ability

It is clear from the research literature that high-ability participants outperform low-ability participants on comprehension measures (e.g., Baker & Brown, 1984; Oakhill, 1993; Perfetti, 1985; Shapiro, 2004). Our results showed that high-ability participants performed consistently better than low-ability participants on the measures for the pain text. The findings were convergent with the results of Linderholm et al.'s (2000) study, which showed that high-skilled college students performed better than low-skilled peers when reading a difficult text.

However, a significant effect of reading ability emerged only on the textbase questions for the diabetes text. One possible explanation is that the diabetes text was more difficult than the pain text. The diabetes text contained more idea units and more difficult concepts than did the pain text, and the text may have been too difficult for these young readers to understand. Thus, although there was a tendency for high-ability readers to perform better than low-ability readers on the free recall and posttest inference questions, the effect of reading ability was not significant on those measures.

Comprehension as a Function of Interaction between Text Coherence and Reading Ability

The other purpose of this study was to examine the interaction between text coherence and reading ability. There was no interaction between text coherence and reading on most measures. The results indicated that text coherence was of equal benefit to readers at both high and low reading ability. This finding supported Linderholm et al.'s (2000) study, which indicated that high and low ability students improved their comprehension equally when they read coherent texts.

However, there was a significant interaction between text coherence and reading ability on the posttest inference questions for the pain text. That is, low-ability readers' deep comprehension was improved when they read the coherent text, whereas high ability readers' deep comprehension was not improved. Why did this significant interaction of text coherence and reading ability appear on the inference questions for the pain text?

One possible explanation is that the revised pain text provided an effective "scaffold" that helped low-ability readers comprehend better. That is, the difficulty level of the revised pain text, which was from a 7th-grade biology textbook that was above the participants' reading level, was appropriate for the low-ability participants. The revised version clarified implicit concepts and repaired coherence breaks, and fewer inferences had to be generated while reading. The low-ability readers may have had sufficient cognitive resources to process the textbase information in the revised text, integrate it with their background knowledge, and then construct a meaningful mental representation. On the other hand, the high-ability readers may not have needed the supplemental information provided by the revised version. They may have already been capable of comprehending the original text, so that the additional support from the revised version did not lead to a significant difference on the deep comprehension measure for the high-ability readers. This finding is particularly meaningful for its educational implications.

Moreover, the "*reverse cohesion effect*" did not emerge in the present study. Some previous studies (e.g., Kamalski et al., 2008; McNamara et al., 1996; McNamara & Kintsch, 1996) indicated that high knowledge readers performed better when they read the incoherent text. Our findings did not support the counter-intuitive "reverse cohesion effect."

Inconsistent Results between the Diabetes Text and the Pain Text

Often researchers use only one text in a study. In the present study, we chose two authentic scientific texts from a 7th-grade textbook, so that we could examine whether there were similar effects across the two texts. If we could obtain similar results from both texts, the evidence would be more solid than results drawn from only a single text.

However, there were inconsistent main effects of text coherence in the two texts, and also inconsistent effects of reading ability. Why did the two texts generate inconsistent results? One possible explanation is that the difficulty level of the pain text was more appropriate to the reading level of our participants than was the difficulty level of the diabetes text. Although both texts were chosen from a 7th-grade textbook, the diabetes text was more difficult than the pain text. There were 46 idea units in the diabetes text as opposed to 17 idea units in the pain text. In addition, the diabetes text contained more unfamiliar terminology than the pain text. Participants recalled only about 27 percent of idea units for the diabetes text, as compared to 43 percent for the pain text.

Another possible explanation is that the difference between the origin and the revised version of the pain text was much greater than that of the diabetes text. According to the readability of both versions of texts rating from ten science teachers, there was a greater coherence difference between origin and revised version for the pain text (d = 1.41), whereas there was less coherence difference between two versions for the diabetes text (d = .5).

Implications

The poor quality of texts of scientific textbooks is a common complaint among educators. It is not surprising that children have difficulty understanding them. As the results of this study demonstrate, improving text coherence appears to be advantageous to young readers. There are several important implications for educators and textbook writers.

For educators, the results suggest that it is important to choose considerate instructional texts for younger students. An instructional text should be written in explicit, direct language that does not require inference-making, so that cognitive load is reduced. In addition, a good text should also contain a clear and concise indication of its macrostructure, including subheadings or topic sentences. The macrostructure represents the global structure of a text (Kintsch, 1998) and cues the most important ideas from the text, which may trigger young readers' background knowledge and encourage them to process the text positively (Kintsch & van Dijk, 1978).

Moreover, it is also important for educators to take account of young children's reading ability when choosing scientific instructional texts. As we know, scientific texts usually contain novel information or explain complicated and challenging concepts. When young readers encounter unfamiliar scientific content, they usually do not have sufficient background knowledge related to the text. Moreover, their reading skills are usually not highly proficient. These young readers simply cannot absorb the information from the text and construct a useful mental representation. Thus, teachers and other educators should be aware of the difficulty of the language and the content of a text, and choose appropriate texts that match young readers' ability.

The interaction of text coherence and reading ability that was found on the posttest inference questions for the pain text is particularly meaningful for its educational implications. The results showed that low-ability young readers' deep comprehension as measured by the inference questions can be improved by reading well-organized, considerate texts. Indeed, low-ability students do need additional assistance when they learn new material. Coherent texts provide explicit information that reduces cognitive load and provides a "*scaffold*" for comprehension (Vygotsky, 1963). Low-ability students may be the ones who benefit most from coherent text; they may thereby be helped to keep pace with their more proficient peers.

For writers of instructional texts, it is important to keep in mind that a good text facilitates the formation of a coherent mental representation. There are several approaches for improving instructional texts. Some approaches (e.g., Beck et al., 1991; Britton & Gulgoz, 1991) use revision principles; they improve texts either by reducing or facilitating a reader's inference-making at either the local level, e.g., making implicit concepts explicit or providing argument overlaps, or the global level, e.g., adding topic sentences or subheadings [other approaches such as those by Linderholm et al. (2000) and Vidal-Abarca et al. (2000) re-arrange the causal order in the text to promote readers' comprehension]. Results of the present study demonstrate that revision principles can successfully improve the coherence of a text and benefit children's shallow and deep comprehension. Thus, these principles provide effective guidelines for writers and editors to develop comprehensible and high-quality instructional texts.

Moreover, the revision principles that have been used in previous studies (English texts) were also successfully applied to Chinese texts. In this study, we found that the original Chinese texts that contained implicit concepts and incoherent sentences could be revised successfully by using the four principles (i.e., *provide the argument-overlap*, *make implicit concepts explicit*, *change the order of sentences and paragraphs*, and *add macro-structure to the tex*t). The effect of text revision not only showed up in participants' performance, but also was revealed in the ten teachers' coherence ratings. However, it is important to note that the improvement of local coherence by using *argument-overlap* may be limited; it is not always necessary with respect to anaphora in Chinese texts. That is, an ellipsis of subject in a sentence is very commonly found in a Chinese text, and Chinese readers are still able to comprehend the text without problem. Tzeng, Chen and Chen (2006) found that Taiwanese children were able to comprehend Chinese narratives with causal, but without anaphoric, coherence. It would be interesting to do a study that examines the effect of anaphoric coherence on Chinese scientific texts.

Limitations

Although the present study showed that there was significant improvement on children's comprehension when they read texts that had been revised to be more coherent, some limitations of the study should be noted.

For educators, it is important to realize that even a coherent, well-designed text is unlikely to communicate to young learners all the information that a mature reader could obtain from it. That is, even though one provides elaborated information to explain complex concepts or additional macrostructure to trigger readers' background knowledge, sometimes young readers will still need extra aids, such as reiterations of ideas or opportunities for discussion, in order to clarify those complex concepts.

Several issues arose that should be considered for future study. First, there may be a confound in the present study. Most of the textbase questions asked for factual information, i.e. propositional information, whereas most of the inference questions asked for causal information. Thus there is a confound—we do not know whether the effect is due to a textbase vs. inference difference or to a propositional vs. causal information difference. It would be interesting to do a study that eliminates this confound in order to see what variable is responsible for the effect. However, it should be pointed out that we were dealing with authentic texts, in which there is a natural relation between these two variables. That is, most of the factual information is presented explicitly and much of the causality is left to be inferred by the reader in authentic texts.

Second, the scores on the background knowledge measure probably did not serve as a valid covariate in the present study. That is, using it, we could not rule out the initial differences in background knowledge among the experimental groups. Perhaps the background knowledge questions that we asked were too general. In order to solve this problem, background knowledge should be measured by the use of more specific questions relating to the two texts.

Third, a qualitative analysis of readers' text comprehension is valuable for determining the misconceptions that they may hold. These misconceptions may impede them from absorbing new information and thus they will not be able to form an accurate mental representation. For example, some children in this study believed that diabetes results from over-intake of sugar. When they read the diabetes text, they were preoccupied by this misconception and ignored the fact that diabetes is caused by a malfunction of insulin production. The results of this misconception could be found in their free-recall protocols and their answers to posttest questions. Thus, it would be useful to conduct a qualitative analysis by using think-aloud to examine more closely what it is that children understand.

Moreover, an experiment to investigate the effect of repeated reading would be meaningful. As we know, the textbook is the most important means of conveying new information to students. Students usually have to read a textbook more than once in order to memorize the novel information and comprehend the complex concepts. In the present study, participants were asked to read the texts as many times as they wanted until they understood the content. However, most participants read them just once and then answered the questions. Thus, it would be of interest to conduct a study that asks participants read the texts either one time or more than once and that compares those two conditions. We could determine the relationship between the number of reading times and text coherence.

Additionally, the present study is lack of any delayed measure. Without this measure, we are unable to capture a whole picture of the effect of text revision for scientific learning. Conducting delayed measures in future studies is necessary to examine the retention effect of text revision.

Finally, it is important to note that motivation is a factor that potentially affects reading comprehension. In the present study, the two scientific texts were anchored at the 7th grade level and thus were difficult for the participants to read. Some of the participants appeared not to be motivated to read the texts when they encountered the unfamiliar content. They quickly gave up reading and answering posttest questions. This low level of engagement may have led to some of the low scores on the posttest. Thus, participants' motivation level should be considered in future research.

Reference

Anderson, R. C., & Pearson, P. D. (1984). A schema-theoretic view of basic processes in reading. In P. D. Pearson, R. Barr, M. L. Kamil, & P. Mosenthal (Eds.), *Handbook of reading research* (pp. 255-259). New York, NY: Longman.

Baker, L., & Brown, A. L. (1984). Metacognitive skills and reading. In P. D. Pearson, R. Barr, M. L. Kamil, & P. Mosenthal (Eds.), *Handbook of reading research* (pp. 353-394). New York, NY: Longman.

Bartlett, F. C. (1932). *Remembering: A study of experimental and social psychology*. Cambridge, UK: Cambridge University Press.

Barton, M. L., Heidema, C., & Jordan, D. (2002). Teaching reading in mathematics and science. *Educational Leadership, 60*, 24-28.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11*, 717-726.

Beck, I. L., McKeown, M. G., & Gromoll, E.W. (1989). Learning from social studies texts. *Cognition and Instruction, 6*, 99-158.

Beck, I. L., McKeown, M. G., Sinatra, G. M., & Loxterman, J. A. (1991). Revising social-studies text from a text-processing perspective: Evidence of improved comprehensibility. *Reading Research Quarterly, 26*, 251-276.

Boscolo, P., & Mason, L. (2003). Topic knowledge, text coherence, and interest: How they interact in learning from instructional texts. *Journal of Experimental Education, 71*, 126-148.

Bower, G. H., Black, J. B., & Turner, T. J. (1979). Scripts in memory for text. *Cognitive Psychology*, *11*, 177-220.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal and Verbal Behavior*, *11*, 717-726.

Britton, B. K., & Gulgoz, S. (1991). Using Kintsch computational model to improve instructional text: Effects of repairing inference calls on recall and cognitive structures. *Journal of Educational Psychology, 83*, 329-345.

Britton, B. K., Van Dusen, L., Gulgoz, S., & Glynn, S. M. (1989). Instructional texts rewritten by five expert teams: Revisions and retention improvements. *Journal of Educational Psychology, 81*, 225-239.

Britton, B. K., Gulgoz, S., & Glynn, S. (1993). Impact of good and poor writing on learners: Research and theory. In B. K. Britton, A. Woodward, & M. Binkley (Eds.), *Learning from textbooks: Theory and practice* (pp. 1-46). Hillsdale, NJ: Lawrence Erlbaum Associates.

Britton, B. K., Woodward, A., & Binkley, M., (Eds.) (1993). *Learning from textbooks: Theory and practice.* Hillsdale, NJ: Erlbaum.

Brown, A. (1982). Learning how to learn from reading. In J. A. Langer & M. T. Smith-Burke (Eds.), *Reader meets author: Bridging the gap* (pp. 26-54). Newark, DE: International Reading Association.

Chall, J. S., & Conard, S. S. (1991). *Should textbooks challenge students?* New York, NY: Teachers College Press.

Chambliss, M. J. (1994). Evaluating the quality of textbooks for diverse learners. *Remedial and Special Education, 15*, 348-362

Chambliss, M. J. (2002). The characteristics of well-designed science textbooks. In J. Otero, J. A. Leon, & A. C. Graesser (Eds.), *Psychology of science text comprehension* (pp. 51-72). Mahwah, NJ: Lawrence Erlbaum Associates.

Cook, L. K., & Mayer, R. E. (1988). Teaching readers about the structure of scientific text. *Journal of Educational Psychology, 80*(4), 448-456.

Davison, A. (1984). Readability-appraising text difficulty. In R. C. Anderson, J. Osborn, & J. Tierney (Eds.), *Learning to read in American school: Basal readers and content texts* (pp. 121-139). Hillsdale, NJ: Lawrence Erlbaum Associates.

Dole, J. A., Duffy, G. G., Roehler, L. R., & Pearson, P. D. (1991). Moving from the old to the new: Research on reading comprehension instruction. *Review of Educational Research, 61*, 239-264.

Duffy, T. M., Higgins, L., Mehlenbacher, B., Cochran, C., Wallace, D., Hill, C., Haugen, D., McCaffrey, M., Burnett, R., Sloane, S., & Smith, S. (1989). Models for the design of instructional text. *Reading Research Quarterly, 24*, 434-437.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102*, 211-245.

Gilabert, R., Martinez, G., & Vidal-Abarca, E. (2005). Some good texts are always better: Text revision to foster inferences of readers with high and low prior background knowledge. *Learning and Instruction, 15*, 45-68.

Ging, L. (1994). Readability of high school textbook. *Educational Research and Information*, *3*, 113-127 (Taiwan).

Goldman, S. R., & Bisanz, G. L. (2002). Toward a functional analysis of scientific genres: Implications for understanding and learning processes. In J. Otero, J. A. Leon, & A. C. Graesser (Eds.), *Psychology of science text comprehension* (pp. 1-15). Mahwah, NJ: Lawrence Erlbaum Associates.

Graesser, A. C., Leon, J. A., & Otero, J. (2002). Introduction to the psychology of science text comprehension. In J. Otero, J. A. Leon, & A. C. Graesser (Eds.), *Psychology of science text comprehension* (pp. 1-15). Mahwah, NJ: Lawrence Erlbaum Associates.

Graesser, A. C., McNamara, D. S., & Louwerse, M. M. (2003). What do readers need to learn in order to process coherence relations in narrative and expository text? In A. P. Sweet, & C. E. Snow (Eds.), *Rethinking reading comprehension* (pp. 82-98). New York, NY: Guilford Press.

Graesser, A. C., Millis, K. K., & Zwaan, R. A. (1997). Discourse comprehension. *Annual review of psychology*, *48*, 163-189.

Graesser, A. C., Singer, M., & Trabasso, T. (1994). Constructing inferences during narrative text comprehension. *Psychological Review, 10,* 371-395.

Graves, M. F., Prenn, M. C., Earle, J., Thompson, M., Johnson, V., & Slater, W. H. (1991). Improving instructional text: Some lessons learned. *Reading Research Quarterly, 26*, 110-122.

Just, M. A., & Carpenter, P. A. (1987). *The psychology of reading and language comprehension*. Boston, MA: Allyn and Bacon.

Kamalski, J., Sanders, T., & Lentz, L. (2008). Coherence marking, prior knowledge, and comprehension of informative and persuasive texts: Sorting things out. *Discourse Processing, 45*, 323-345.

Kintsch, W. (1994). Text comprehension, memory, and learning. *American Psychologist, 49*, 292-303.

Kintsch, W. (1988). The use of knowledge in discourse processing: A construction-integration model. *Pychological Review, 95*, 163-182.

Kintsch, W. (1998).*Comprehension: A paradigm for cognitio*n. Cambridge, UK: Cambridge University Press.

Kinstch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85,* 363-394.

Kintsch, W. & Vipond, D. (1979). Reading comprehension and readability in educational practice and psychological theory. In L. G. Nilsson (Ed.), *Perspectives on memory research*: *Essays in honor of Uppsala University's 500th anniversary* (pp. 329-365). Hillsdale, NJ: Erlbaum.

Kang Hsuan (2006). *Science and life technology*. Taipei, R.O.C.: Kang Hsuan Educational Publishing Group.

Ko, H. (1999). *The reading difficulty diagnostic test.* Taipei, R.O.C.: The Special Education Group of the Ministry of Education.

Linderholm, T., Everson, M. G., van den Broek, P., Mischinski, M., Crittenden, A., & Samuels, J. (2000). Effects of causal text revisions on more- and less-skilled readers' comprehension of easy and difficult texts. *Cognition and Instruction, 18*, 525-556.

Lorch, R. F., & Lorch, E. P. (1996). Effects of organizational signals on free recall of expository text. *Journal of Educational Psychology, 88(1*), 38-48.

Lehman, S., & Schraw, G. (2002). Effects of coherence and relevance on shallow and deep text processing. *Journal of Educational Psychology, 94,* 738-750.

Mandler, J. M., & Johnson, N. S. (1977). Remembrance of things passed: Story structure and recall. *Cognitive Psychology, 9*, 111-151.

Magliano, J. P., & Millis, K. K. (2004). Assessing reading skill with a think-aloud procedure. *Cognition and Instruction, 21,* 251-283.

Magliano, J. P., Trabasso, T., & Graesser, A. C. (1999). Strategic processing during comprehension. *Journal of Educational Psychology, 91*, 615-629.

Mckeown, M. G., Beck, I. L, Sinatra, G. M., & Loxterman, J. A. (1992). The contribution of prior knowledge and coherent text to comprehension. *Reading Research Quarterly, 27*, 79-93.

McNamara, D. S., Kintsch, E., Songer, N. B., & Kintsch, W. (1996). Are good texts always better? Interactions of text coherence, background knowledge, and levels of understanding in learning from text. *Cognition and Instruction, 14*, 1-43.

McNamara, D. S., & Kintsch, W. (1996). Learning from texts: Effects of prior knowledge and text coherence. *Discourse Processes, 22*, 247-288.

Meyer, B. J. F. (2003). Text coherence and readability. *Topics in Language Disorders, 23,* 204-222.

Meyer, B. J. F., Brandt, D. M., & Bluth, G. J. (1980). Use of top-level structure in text: Key for reading comprehension of ninth-grade students. *Reading Research Quarterly, 16*(1)*,* 72-103.

Oakhill, J. V. (1984). Inferential and memory skills in children's comprehension of stories. *British Journal of Educational Psychology, 54*, 31-39.

Oakhill, J. V. (1993). Children's difficulties in reading comprehension. *Educational Psychology Review, 5*, 223-237.

Oakhill, J. V., & Yuill, N. (1996). Higher order factors in comprehension disability: Processes and remediation. In C. Cornaldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and Intervention* (pp. 69-92). Mahwah, NJ: Lawrence Erlbaum Associates.

O'Reilly, T., & McNamara, D. S. (2007). Reversing the reverse cohesion effect: Good texts can be better for strategic, high-knowledge readers. *Discourse Processes, 43*, 121-152.

Perfetti, C. A. (1985). *Reading ability*. New York, NY: Oxford University Press.

RAND Reading Study Group. (2002). *Reading for understanding*. Santa Monica, CA: RAND.

Rumelhart, D. E. (1975). Notes on a schema for stories. In D. G. Bobrow & A. Collins (Eds.), *Representation and understanding* (pp. 211-236). Hillsdale, NJ: Erlbaum.

Sanders, T. J. M., & Noordman, L. G. M. (2000). The role of coherence relations and their linguistic marker in text processing. *Discourse Processes*, *29*, 37-60.

Sawyer, M. H. (1991). A review of research in revising instructional text. *Journal of Reading Behavior, 23*, 307-333.

Shapiro, A. M. (2004). How including prior knowledge as a subject variable may change outcomes of learning research. *American Educational Research Journal, 41*, 159-189.

Su, Y. F., & Lin, C. S. (1992). Effects of metacognitive training program on reading comprehension and metacognitive skills of sixth grade less skilled readers. *Bulletin of Educational Psychology, 25*, 245-267.

Tzeng, Y., Chen, P., & Chen, M. (2006). *Children's comprehension of narratives with causal but without anaphoric coherence.* Paper presented at the Sixteen Annual Meeting of the Society for Text and Discourse, Minneapolis, MN.

Trabasso, T., Secco, T., & van den Broek, P. (1984). Causal cohesion and story coherence. In H. Mandl, N. L. Stein, & T. Trabasso (Eds.), *Learning and comprehension of text* (pp. 83-111). Hillsdale, NJ: Erlbaum.

van den Broek, P. (1994). Comprehension and memory for narrative texts: Inferences and coherence. In M. A. Gernbacher (Ed.), *Handbook of psycholinguistics* (pp. 539-588). New York, NY: Academic.

van den Broek, P. (1990). Causal inferences and the comprehension of narrative texts. In A. C. Graesser & G. Bower (Eds.), *Inferences and text comprehension* (pp. 175-196). San Diego, CA: Academic Press.

van den Broek, P., & Kremer, K.E. (2000). The mind in action: What it means to comprehend during reading. In B. M. Taylor, M. F. Graves, & P. van den Broek (Eds.), *Reading for meaning: Fostering comprehension in the middle grades* (pp. 1-31). New York, NY: Teachers College Press.

van den Broek, P.,Young, M., Tzeng Y., & Linderholm, T. (1999). The landscape model of reading: Inferences and the online construction of a memory representation. In H. van Oostendorp & S. R. Goldman (Eds.), *The construction of mental representations during reading* (pp. 71-98). Mahwah, NJ: Erlbaum.

van Dijk, T. A., & Kintsch, W. (1983). *Strategies of discourse comprehension.* New York, NY: Academic Press.

Vidal-Abarca, E., Martinez, G., & Gilabert, R. (2000). Two procedures to improve instructional text: Effects on memory and learning. *Journal of Educational Psychology, 92*, 107-116.

Voss, J. F., & Silfies, L. N. (1996). Learning from history text: The interaction of knowledge and comprehension skill with text structure. *Cognition and Instruction, 14*, 45-68.

Vygotsky, L. S. (1963). Learning and mental development at school age. In B. Simon & J. Simon (Eds.), *Educational psychology in the U.S.S.R*. (pp. 21-34). London, UK: Routledge & Kegan Paul.

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Appendix A: Examples of revision principles using in the present study

1. Argument-overlapped principle:

The original version. 第二型多發生在 40 歲以上的中老年人，因為身體對胰島素的反應變差…許多病患都是罹病多年後以診斷出來，95%的糖尿病屬於此型，肥胖者與近親有糖尿病者都是高危險群。

The revised version. 第二型多發生在 40 歲以上的中老年人，因為身體對胰島素的反應變差…許多病患都是罹病多年後以診斷出來，大部分的糖尿病都是多屬於第二型，肥胖者與近親有糖尿病者都是第二型糖尿病的高危險群。

2. Make implicit concepts explicit:

The original version. 疼痛是很重要的機制，它可以讓我們迅速警覺而身體外在和內部的變化，…。

The revised version. 疼痛是人體內很重要的警示功能，它可以告訴我們身體外面的危險…，也可以提醒我們身體內的病變…。

3. Change the order of the sentences and paragraphs

The original version. 人體有兩種減輕疼痛的機制，第一種機制是分泌腦內啡。腦內啡和嗎啡相似，當人們感到劇烈疼痛時，大腦會分泌腦內啡…，這對於嚴重、激烈的疼痛很有效…

The revised version. 人體有兩種減輕疼痛的機制，第一種機制是分泌腦內啡，這種機制對於嚴重、激烈的疼痛很有效，當人們感到劇烈疼痛時，大腦會分泌腦內啡，腦內啡和嗎啡相似…。

4. Add macro-structure to the text:

The original version. 常見的糖尿病有兩類型，第一型多發生在兒童及青少年，患病原因是自己體內的抗體破壞了胰臟功能，而無法製造胰島素…。第二型多發生在 40 歲以上的中老年人，因為身體對胰島素的反應變差…。

The revised version. 糖尿病依照其成因，可分為兩類型，第一型起因於胰島素缺乏，多發生在兒童及青少年，病原因是自己體內的抗體破壞了胰臟功能，而無法製造胰島素…。第二型起因於胰島素功能不良，多發生在 40 歲以上的中老年人，因為身體對胰島素的反應變差…。

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文章連貫性、閱讀能力與兒童科學理解表徵之研究

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本研究之目的有三：(1）探討文章連貫性的改寫原則是否能有助於改善學童的文本；(2）文章連貫性的編寫原則是否有助於修改科學性的文本；(3）探討讀者閱讀能力和文章連貫性是否有交互作用存在。本研究選取兩篇科學性文章的自然文本，依據四個文章編修原則(論詞重複原則、概念清晰化原則、改變句子和段落順序原則及增加鉅觀結構)來進行改寫。受試者為 91 名國小六年級學生，依其閱讀能力分為高能力和低能力兩組，並隨機分派閱讀「原始版本」或「改編版本」。所有的受試者均接受「自由回憶」、「文本理解」和「推論理解」的測量。結果顯示：閱讀改編版本(連貫性高)學童的理解表現優於原始版本的學童。高能力的學童表現的較低能力的學童佳。閱讀能力和文章連貫性的交互作用效果發生於其中一篇文章推論層次的理解。此交互作用代表低能力的讀者在回答推論層次的問題時，獲益於文章連貫性的操弄，而高能力的讀者並沒有這樣的現象。本文最後就此一發現探討其教育上的應用。

關鍵詞：文章連貫性、閱讀能力、閱讀理解