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Influences of text difficulty and reading ability on learning illustrated science texts for children: An eye movement study

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ABSTRACT

In this study, eye movement recordings and comprehension tests were used to investigate children's cognitive processes and comprehension when reading illustrated science texts. Ten-year-old children (N = 42) who were beginning to read to learn, with high and low reading ability read two illustrated science texts in Chinese (one medium-difficult article, one difficult article), and then answered questions that measured comprehension of textual and pictorial information as well as text-and-picture integration. The high-ability group outperformed the low-ability group on all questions. Eye movement analyses showed that both group of students spent roughly the same amount of time reading both articles, but had different methods of reading them. The low-ability group was inclined to read what seemed easier to them and read the text more. The high-ability group attended more to the difficult article and made an effort to integrate the textual and pictorial information. During a first-pass reading of the difficult article, high- but not low-ability readers returned to the previous paragraph. The low-ability readers spent more time reading the less difficult article and not the difficult one that required teachers' attention. Suggestions for classroom instruction are proposed accordingly.

1. Introduction

Informational texts either in print or digital have one common characteristic, i.e., they usually have multiple representations (text, pictures, tables, etc.) in one article or in one web page. Theories of text and picture comprehension suggest that multiple representations facilitate reading comprehension if readers organize and integrate textual and pictorial information effectively according to their prior knowledge (Mayer, 2005; Schnotz & Bannert, 2003; Schnotz et al., 2014). However, multimedia presentations do not always improve comprehension or learning. Some researchers have shown that adding scientific illustrations to a text (McCabe & Castel, 2008) or mathematical illustrations to a problem-solving question (Berends & Van Lieshout, 2009; Ögren, Nyström, & Jarodzka, 2017) might have unfriendly effect.

Ten-year-old students in the fourth grade, who are at the beginning of the reading to learn stage (Chall, 1983), encounter academic requirements that include comprehension of increasingly complex texts (McMaster, Espin, & van den Broek, 2014;

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Sweet & Snow, 2003), for example, science texts. A science article is a typical formational text, and the picture–text ratio has expanded considerably from the past to the present in science textbooks (Pozzer & Roth, 2003; Slough, McTigue, Kim, & Jennings, 2010).

1.1. Background theories of text-and-picture reading

Various text and picture (including graphs & illustrations) reading theories explain the potentially beneficial effects of multimedia materials. Dual coding theory (Paivio, 1990) suggests that better memory for text accompanied by pictorial information can be attributed to a dual coding advantage: The activation of both verbal and visual representations in working memory makes it easier to connect the two codes, and consequently, to remember and retrieve information. Beneficial effects of multimedia materials on comprehension have been explained by the cognitive theory of multimedia learning (Mayer, 2005) and the integrated model of text and picture comprehension (Schnotz et al., 2014; Schnotz & Bannert, 2003).

The cognitive theory of multimedia learning proposed by Mayer (2005) suggests that text-and-picture reading involves three cognitive processes: 1) *selecting* relevant information, which occurs when readers devote attention to the text and relevant elements from the picture, and involves bringing external representations into working memory; 2) *organizing* selected information, in which verbal and pictorial models of selected textual and pictorial information are constructed separately in working memory; and 3) *integrating* the constructed verbal and pictorial models with existing prior knowledge to form a coherent mental model.

According to the integrated model of text and picture comprehension (Schnotz & Bannert, 2003; Schnotz et al., 2014), two different cognitive processes are involved in reading text-and-picture articles. One processing system is descriptive and involved in text reading, and the other is depictive and involved in picture reading. According to this model, text comprehension is a descriptive process that involves constructing surface textual knowledge, producing several propositional representations of the text content, and forming a mental model of the text theme. In contrast, picture comprehension is a depictive process that involves perceiving an external picture, creating a visual image, and constructing the picture's propositional representation and mental model. The information in the depictive process is based on structure mapping of analogy relations between depictive representations (Gentner, 1989). Readers deal with a picture's semantic components to comprehend rather than perceive it. The propositional representations and mental models in the two processing systems continuously interact. Both Mayer (2005) and (Schnotz et al., 2014; Schnotz & Bannert, 2003) theories of text and picture comprehension suggest that multiple representations facilitate reading comprehension. The premise is that the reader must encode both verbal and pictorial information presented in the article. However, the question of how young children with different reading abilities encode and connect the multiple representations (text and picture) while reading illustrated science texts, and whether text difficulty influences this process still demand further examination. The purpose of this study is to explore these questions by investigating how fourth graders with varying reading ability read science texts of varying difficulty.

1.2. Thinking-aloud protocols as a research tool in illustrated text reading research

Previous research has demonstrated that the multiple representation effect is inconsistent in children. Some studies have shown that illustrations inhibit reading comprehension (Harber, 1983), while others have demonstrated illustration facilitation of reading comprehension across different levels of reading ability (Small, Lovett, & Scher, 1993), or only for high-ability young readers (Hannus & Hyönä, 1999), only for low-ability young readers (Rusted & Coltheart, 1979). We speculated that young readers may have limited knowledge of the function of illustrations, and consequently do not pay enough attention to them. The process approach presented by thinking-aloud protocols and eye-tracking methodology offer an opportunity allowing for indirect (thinking-aloud) and direct (eye tracking) observations of reading behavior to test these assumptions.

Moore and Scevak (1997) used think-aloud protocols (i.e. report about one's mental processes) to investigate the reading strategies across different reading ability levels and ages. They asked students in grades five, seven, and nine to read a science article with illustrations (including tables and diagrams). Students were instructed to stop reading and report what they read and what they were thinking when they encountered red dots (inserted by the researchers) in the article. Coding the think-aloud data revealed that *without reference to illustrations* and *with reference to illustrations* were two major categories. Sub-categories for *without reference to illustrations* focused on text details, main text ideas, text themes, general strategies, artifact production, and artifact use. Sub-categories for *with reference to illustrations* focused on illustration details, main illustration ideas, illustration themes, and illustration use. This study found that the biggest differences in reading patterns between students in different grades were in the use of text themes and illustrations. Text themes were reported by 5%, 5%, and 52% of fifth, seventh, and ninth graders, respectively, and use of illustrations was reported in 8%, 13%, and 48% of fifth, seventh, and ninth graders, respectively. While reading science text, the fifth graders focused attention on text details, the seventh graders could hold the main idea of the text, and the ninth graders paid attention to the illustrations and connected text and illustration information. However, a cluster analysis showed that reading ability did not distinguish reading strategy use by students in any grade. These results are inconsistent with most other text reading research (Braten & Stromso, 2003; Dermitzaki, Andreou, & Paraskeva, 2008) that found that reading ability was tightly linked to reading strategy use, and reading strategy use was positively correlated with reading comprehension.