INTERNATIONAL LITERACY ASSOCIATION
READING RESEARCH QUARTERLY

Fourth Graders' Cognitive Processes and Learning Strategies for Reading Illustrated Biology Texts: Eye Movement Measurements

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ABSTRACT

Previous research suggests that multiple representations can improve science reading comprehension. This facilitation effect is premised on the observation that readers can efficiently integrate information in text and diagram formats; however, this effect in young readers is still contested. Using eye-tracking technology and sequential analysis, this study investigated students' reading strategies and comprehension of illustrated biology texts in relation to adult readers' performance. The target population was fourth-grade students with high reading ability, and the control group was university students. All participants read a biology article from an elementary school science textbook containing two illustrations, one representational and one decorative. After the reading task, participants answered questions on recognition, textual, and illustration items. Unsurprisingly, the university students outperformed the younger students on all tests; however, more interestingly, eye movement patterns differed across the two groups. The adult readers demonstrated bidirectional reading pathways for both text and illustrations, whereas the fourth graders' eye fixations only went back and forth within paragraphs in the text and between the illustrations, but made fewer references to both text and illustration. This suggests that regardless of their high reading ability, fourth-grade students' visual literacy is not mature enough to perceive connections between corresponding features of different representations crucial to reading comprehension. Despite differences in cognitive processes between adult readers and young readers, high-ability young readers still have certain capabilities in reading comprehension. The results of sequential analysis showed that they looked back to previous paragraphs frequently, indicating that they were monitoring their comprehension.

Reading plays an important role in education, particularly in the sciences. The renowned journal *Science* even published a special volume discussing the relation between science and reading that covered topics such as cognitive processes involved in science reading (van den Broek, 2010), challenges in reading science-related texts (Snow, 2010), and the impact of integrating scientific inquiry, teaching, and learning into syllabi for kindergarten through high school (Pearson, Moje, & Greenleaf, 2010).

Students are commonly exposed to visual representations of information in textbooks; the picture-to-text ratio in science textbooks has increased considerably in recent years (Cook, 2006; Ferk, Vrtacnik, Blejec, & Gril, 2003; Pozzer & Roth, 2003; Slough, McTigue, Kim, & Jennings, 2010; Unsworth, 2001). To successfully comprehend an illustrated science text involves complicated and cognitively

Reading Research Quarterly, 51(1)
pp. 93–109 | doi:10.1002/rrq.125

demanding processes (Ainsworth, 2006; Mason, Tornatora, & Pluchino, 2013). According to the cognitive theory of multimedia learning (Mayer, 2005), textual representations and pictorial representations are processed through two cognitive subsystems: the verbal channel and the pictorial channel. Learning from multimedia entails several coordinated processes, including selecting relevant words and images, organizing the selected words into a verbal mental model and selected images into a pictorial mental model, and finally, integrating the verbal model and the pictorial model with readers' prior knowledge into a coherent mental representation. It was therefore hypothesized that connecting textual and pictorial representations is important for good reading comprehension. Good reading abilities and strong cognitive capabilities facilitate these cognitive processes. It is still unclear whether young readers, such as elementary school students, can perform these processes to construct mental representations to acquire science concepts. Educators and publishers rely on illustrations as a tool to develop students' science knowledge. Therefore, the extent to which elementary students make use of illustrations in science texts to build knowledge and conceptual understanding is a significant question.

Although research on visual representations and multiple representations has received a great deal of attention in science pedagogy, the focus has primarily been on adult readers (Butcher, 2006; Hegarty, 1992; Hegarty & Just, 1993; Jian & Wu, 2015; Jian, Wu, & Su, 2014; Johnson & Mayer, 2012) and middle school students (Cook, Carter, & Wiebe, 2008; Cook, Wiebe, & Carter, 2008; Won, Yoon, & Treagust, 2014; Wu, Lin, & Hsu, 2013), rather than young readers (Hannus & Hyönä, 1999; Mason et al., 2013). From a developmental perspective, a reader may adopt different reading strategies across the life span. Therefore, generalizing these findings to young students would be inappropriate.

Previous research has confirmed a consistent advantage of multiple representations in science reading among adults; that is, an adult reader would demonstrate better reading comprehension and acquire more complex science concepts when both verbal and pictorial representations, rather than just one, are provided (Carney & Levin, 2002; Hegarty & Just, 1993; Mayer, 2005). These findings support theories on text and picture comprehension (Mayer, 2005; Schnotz, 2005; Schnotz & Bannert, 2003). However, research has yielded inconsistent findings for this effect in young students for science reading (Hannus & Hyönä, 1999; McTigue, 2009; Segers, Verhoeven, & Hulstijn-Hendrikse, 2008). The multiple-representation effect involves reading verbal and graphical information in the text and linking both representations to create a mental model. For young readers, I am concerned with a more basic question that is examined in the present study: Do young students read only one representation or both, and if the latter, can they create a model using both representations?

Visual Representations in Science Education

Visual representations are especially critical in the communication of science concepts (Ainsworth, 2006; Mathewson, 1999). Science articles usually consist of text and graphics, and reading comprehension is decided based on whether a reader is capable of using these multiple representations of text and graphics (Seufert, 2003). Theories on learning with multiple representations (Ainsworth, 2006) and on text and picture comprehension (Mayer, 2005; Schnotz & Bannert, 2003) explain that for conceptual understanding, learners first need to understand each representation and select important information, then organize these in relation to each other, integrating representations and prior knowledge. Although the importance of visual representations in science is well documented, limited research has been conducted on the role of visual representations in science teaching or learning (Cook, 2006; Pozzer-Ardenghi & Roth, 2005).

Cook and her colleagues (Cook, 2006; Cook, Carter, & Wiebe, 2008) conducted a series of pioneering studies that presented empirical evidence and instructional designs related to visual representations in science education. In a review of theoretical concepts (Cook, 2006), instructional designs were tested in accordance with learning theories (e.g., dual coding theory: Paivio, 1990; cognitive load theory: Sweller, van Merrienboer, & Pass, 1998). It was found that learners' characteristics, especially prior knowledge, are important factors that mediate the effectiveness of multiple-representation design principles.

Eye tracking is a long-standing technology used to investigate reading processes (Rayner, 1998). Saccades (eye movements), fixations (one's eyes stay on a certain location without moving), and regression (refer back to objects that have been previously read) are the basic features of reading behavior. To understand the role of prior knowledge, Cook, Carter, and Wiebe (2008) conducted two experiments to investigate how high school students with different levels of prior knowledge viewed and interpreted graphics on cellular transport from biology textbooks. The researchers collected three types of data—eye tracking, interviews, and questionnaires—to investigate differences in perceived salient features of the graphics, graphical interpretations, and processing difficulties in understanding the graphics. Cook et al. found that students with a low level of prior knowledge focused on surface features of the graphics to understand the represented concepts but still experienced difficulties in understanding the graphics; in contrast, students with high prior knowledge were more likely to attend to the thematically relevant content in the graphics.

In a similar study, Cook, Wiebe, and Carter (2008) found that students with high prior knowledge transitioned more frequently between representations of molecular cellular transport, whereas students with low prior knowledge transitioned more frequently between representations of macroscopic cellular transport and between macroscopic and molecular representations. This was consistent with their previous research (Cook, Carter, & Wiebe, 2008) indicating that those with high levels of prior knowledge distribute their visual attention on conceptually relevant features, whereas those with low levels of knowledge focused on surface features. Furthermore, students with less domain knowledge experienced greater difficulties in forming links across different representational levels.

Overall, the research discussed previously indicated that middle school students with low prior knowledge tend to apply superficial processing strategies and have difficulties in identifying relevant information in representations (Ainsworth, 2008; Cook, Carter, & Wiebe, 2008; Kozma, 2003).

Further, in the literature on illustrated science reading, Jian and Wu (2015) used eye-tracking technology to investigate which strategies adult readers use when reading an illustrated science text. Seventy-one undergraduate participants read a scientific article containing one diagram. The article described the pathways of the fear response and awareness in the human brain. The diagram section had seven technical terms referring to the brain, which were the same as those contained within the text section. The results showed that a text–diagram referencing strategy was commonly used. Although some readers adopted the strategy of reading the diagram or text first, they all performed text–diagram referencing on the second round of reading. Very few readers (11%) did not reference the diagram. The participants who ignored it performed more poorly on questions that tested understanding of basic facts as compared with those who made text–diagram references, indicating that dual coding theory may explain the phenomenon and implying that at least some participants extracted semantic and spatial information by looking at the diagram.

Research on Young Students' Ability to Read Illustrated Science Texts

Elementary school students' reading development is considerably different from those of adolescents, suggesting that they may have very different reading strategies and cognitive processes for reading illustrated science texts with both types of representations.

Moore and Scevak (1997) used think-aloud protocols to investigate reading strategies for text and illustration among primary and secondary school students. Fifth-, seventh-, and ninth-grade students were asked to read science texts containing visual representations (tables, diagrams). The results indicated developmental differences. Whereas older students demonstrated explicit linking of information from text and visual representations, this was not as evident in the younger students; the fifth graders focused on detailed information in the text but seldom read information presented through illustrations.

Norman (2012) used a think-aloud protocol to investigate the relationship between graphical reading processes and reading comprehension in young readers. Second-grade students with high, medium, and low reading ability read two informational texts (one about dinosaur fossils and the other about weather watching) containing several visual representations (photographs, realistic drawings, maps, flowcharts, diagrams, etc.). The results showed that the number of times the students with high reading ability used graphic reading strategies was significantly correlated with scores on the retelling measure for the dinosaur fossils text but not for the retelling measure of the weather-watching text or the comprehension question measure of either book. Although this study provided various visual representations as reading materials, including decorative pictures and representational diagrams, they were not analyzed separately.

McTigue (2009) investigated whether the principles of multimedia learning (Mayer, 2005) demonstrated by college-age readers can be generalized to young readers. Sixth-grade students were randomly assigned to one of four groups, wherein they had to read two explanatory passages on life sciences and physical science presented in the following format: without illustrations (control group), illustrations with labels for each part (parts group), illustrations with labels for each major process (steps group), or illustrations with labels for each part and major process (parts-and-steps group). The results showed that for the life sciences text, students demonstrated modest improvement by the addition of diagrams, with the parts and steps groups outperforming the control group. The parts-and-steps group's performance was poorer than that of the control group. For the physical science text, the diagrams did not benefit students. The disparity between these results and Mayer and Gallini's (1990) study on college students, wherein the parts-and-steps group outperformed the other three groups (text only, text with label diagram, text with step diagram), led McTigue to conclude that young readers may not possess the sophisticated strategies needed to deal with the expository, complex text-and-graphics combination that adult readers have.

In sum, research indicates that older and younger readers employ different reading strategies (Moore & Scevak, 1997). The number of times graphic reading strategies are used by second graders was not highly correlated with their reading comprehension performance (Norman, 2012), and although research on adults supported the multimedia learning theory (Mayer, 2005), it cannot be directly applied to young readers in a classroom setting (McTigue, 2009) because the methods used to obtain these findings—students' self-reports and learning outcomes—reflect conscious processes and do not evaluate unconscious cognitive processes in everyday reading situations.

Eye tracking is an online method that records the position and fixations of the eyes as readers move across visual stimuli (e.g., text, graphics). It permits several indexes of processing to be collected simultaneously with high temporal and spatial resolution, such as what sequences readers read, what stimuli they looked at, and how long they looked at the stimuli (Hyönä, Lorch, & Kaakinen, 2002; Mikkilä-Erdmann, Penttinen, Anto, & Olkinuora, 2008). The eye-mind hypothesis (Just & Carpenter, 1980) theoretically underlies this methodology. It assumes that human gaze is closely linked to individual attentional processes while visual information is being observed. In other words, it corresponds to the relationship between perceptual and cognitive processes. Eye tracking used to examine young students' cognitive processes when reading texts with diagrams cannot only provide empirical evidence for expanding the applicability of the multimedia learning theory but also has implications for modifying classroom instruction.

Such eye-tracking studies on young students' ability to read and comprehend illustrated science texts are limited. The earliest classical research was conducted by Hannus and Hyönä (1999). Experiment 2 of their study examined the effects of illustrations in an elementary school science textbook on learning among fourth-grade students with high and low intellectual ability. Although the total time spent on reading the text did not differ significantly between groups, they allocated visual attention to different locations on the text and graphics; high-ability students devoted relatively more time to studying pertinent segments of text and illustrations and engaged in more back-and-forth eye movements between text and a relevant illustration than did low-ability students. This suggests that high-ability students utilize more mature learning strategies, concentrating on pertinent information and integrative processing. Interestingly, in this experiment, for both high- and low-ability readers, reading behavior was heavily driven by the text, with minimal inspection of illustrations. The fixation duration on the illustrations was approximately 6%, even though there were three to six explanative illustrations (e.g., depiction of the development of a fly from an egg to an adult fly) and nonexplanative illustrations (e.g., a photograph of a fly) for each text. This fixation duration ratio for illustrations was much lower than that found among adults, reported to be approximately 20–30% when reading science texts with only one or two graphics (Jian & Wu, 2012, 2015; Schmidt-Weigand, Kohnert, & Glowalla, 2010).

Recently, Mason et al. (2013) used eye-tracking technology to investigate reading processes for text and illustrations among fourth graders. The researchers examined the applicability of the cognitive theory of multimedia learning (Mayer, 2005), emphasizing the role of integration, on young readers. The students were asked to read an illustrated science text describing the characteristics of air. Mason et al. used cluster analysis to classify the readers into three groups by their eye movement patterns: high, intermediate, and low integrators. Compared with intermediate and low integrators, high integrators spent the longest fixation time on the picture during the first-pass reading, made more attempts to integrate verbal and pictorial representations, and spent the most time integrating words and graphics during text rereading or illustration reinspection. Greater integrative processing of illustrated text was associated with better performance on reading comprehension tests. Thus, the results support the theoretical assumptions of the cognitive theory of multimedia learning, suggesting that the integration of information from text and pictures is essential for successful comprehension of an illustrated text. Students who performed fewer text and picture transformations had poorer reading comprehension scores. Although the study was well designed, the learning material only allowed inferences for a single illustration, not on detailed processes within illustrations, and the researchers could not ascertain whether young readers were capable of identifying and referencing relevant information across text and graphics. Multiple representations from existing science textbooks better approximate ordinary reading materials and reading conditions in school or daily life.

Limitations of Previous Research

There are several important limitations in the previous research that I addressed in the present study. First, the processes involved in reading illustrated science texts in young readers is still unclear. Although a few studies have focused on the difficulties that younger readers experience with multiple representations, most used think-aloud protocols that may have interfered with readers' cognitive processes (Moore & Scevak, 1997; Norman, 2012) or outcome measures (Brookshire, Scharff, & Moses, 2002; McTigue, 2009; Rusted & Coltheart, 1979; Segers et al., 2008; Small, Lovett, & Scher, 1993). The studies seldom used eye trackers to address this issue (Hannus & Hyönä, 1999; Mason et al., 2013).

Second, there is limited direct empirical research that explains young readers' reading pathways and learning strategies. A few previous studies have used eye-tracking technology and sequential analysis to investigate readers' reading pathways only for adult readers, not young readers (Cook, Wiebe, & Carter,, 2008; Hegarty & Just, 1993; Jian et al., 2014). In addition, previous research on young readers using eye-tracking technology (Hannus & Hyönä, 1999; Mason et al., 2013) have reported on the fixation duration and frequency of references to science text and illustration sections but have not provided more detailed information on reading sequences between several paragraphs in a text and different illustrations, nor on the formats that clearly depicted reading pathways and cognitive processes.

Third, a few studies used comprehension tests specifically designed to evaluate graphic memory or comprehension; most only tested participants' ability to read illustrated text (Hannus & Hyönä, 1999; Mason et al., 2013). In these studies, diagram items were provided to evaluate graphic memory and comprehension, contributing significantly to the graphic reading research domain.

Finally, previous research has compared reading strategies of students in different grades (Moore & Scevak, 1997) or indirectly compared the multiple-representation effect for readers of different ages using learning outcome measures. For example, McTigue (2009) conducted a study on sixth-grade students and compared the results with previous research (Mayer & Gallini, 1990) that employed university students as participants.

Studies have not directly compared eye movement patterns of readers across different ages. Thus, none were able to provide insights into differences in reading processes from a developmental perspective. In the present study, I attempted to overcome these research limitations.

The Present Study and Hypotheses

This study is one part of a larger research project designed to examine young students' learning strategies and comprehension of reading illustrated science texts in relation to adult readers' performance. The target population was fourth-grade students with high reading abilities, large vocabularies, and good comprehension skills. Undergraduate students served as the control group. By comparing the two groups, I could investigate what young readers can do and their deficiencies in reading illustrated science texts as compared with undergraduate students with good reading ability and without word identification difficulty.

Fourth-grade readers with high reading abilities and university students read an identical excerpt on biology from an elementary school science textbook. This article contained two types of illustrations, representational and decorative, that depicted parts of a flower and the process of pollination. After the reading task, participants responded to questions on recognition, textual, and illustration items. I designed the first two types of items according to parts of Kintsch's (1988) reading comprehension theory, which indicates that when a person reads the most superficial level of text representation, the syntax and wording of each sentence are maintained in a surface code (I designed the recognition items). The second level is text-based representation, which corresponds to the propositional representation of a text; that is, readers catch the meaning of sentences and the text (I designed the textual items). The third and deepest level is a situation model, representing the result of the interaction between text comprehension and readers' prior knowledge (I did not design corresponding items in this study, and this limitation is discussed in the Limitations section). By combining eye movement data and comprehension performance, we can understand young readers' learning outcomes and identify their reading strategies and cognitive processes.

I analyzed several eye movement indicators: visual attention distribution for text and illustration, reference to relevant parts of the text and illustration, and reading pathways, among others. Prior research in this area guided hypothesis formation, and two hypotheses were formulated. First, regarding the effect of illustrations on reading textual matter, whereas university students have considerable text-and-illustration reading experience and can establish connections between representations of text and illustration (Hegarty, 1992; Hegarty & Just, 1993; Jian & Wu, 2012, 2015; Mayer, 2005), young readers are less capable of using illustrated information (Hannus & Hyönä, 1999; McTigue, 2009; Moore & Scevak, 1997). Therefore, I hypothesized that university students would emphasize the role of illustration, pay more visual attention to the illustration, and refer to both text and illustration more frequently to remember and comprehend the science concept conveyed in the article. Therefore, I expected that university students would have a higher proportion of fixation duration for the illustration, especially for the representational illustration, and have more saccades between text and illustration than the fourth-grade students (hypothesis 1). Analyses of several eye movement indicators (e.g., total reading time, proportion of fixation durations, number of saccades between text and illustration) were conducted to confirm hypothesis 1.

Second, the hypothesis regarding reading strategies and cognitive processes involved with text and illustration comprehension was based on theories that claim that selecting specific information is the first essential step to learning from illustrated texts (Mayer, 2005; Schnotz & Bannert, 2003). According to these theories, a reader who is capable of selecting relevant information from the text and graphics will have more opportunities to organize and integrate these representations to construct a coherent mental representation of the illustrated text. Therefore, I expected that the university students would demonstrate bidirectional reading pathways between text and illustrations, but the fourth-grade students would demonstrate a reading pathway within the single representation of text or illustration (hypothesis 2). Even though the fourth-grade students had high reading ability, I speculated that their reading pathway would differ from that of the adult readers because diagram literacy typically shows slower development than word recognition (Kress & van Leeuwen, 1996; McTigue, 2009; McTigue & Flowers, 2011). I performed transition probabilities and sequential analysis for eye fixations to confirm hypothesis 2.

Method

Participants

Of the 34 participants in the eye movement experiment, 17 were university students (7 males and 10 females, mean age = 21.05 years) from the National Central University in Taiwan, and 17 were fourth-grade students (8 boys and 9 girls, mean age = 10.4 years) from an elementary school in Taiwan. The university students received a small monetary reward for participation (200 New Taiwanese dollars, approximately 5 euros). Parental consent was received for the elementary school students, who were rewarded for their participation with stationery. All participants had normal or corrected-to-normal vision.

The fourth-grade participants in this study were students with high reading ability. Initially, 63 fourth-grade students (33 girls and 30 boys) comprising the three classes at an elementary school in Taiwan were recruited as the subject pool. I conducted the standard Reading Comprehension Screening Test (Ko, 1999) to evaluate the young students' reading comprehension ability. The participation criterion of high reading ability was comprehension test scores exceeding 90% of the nationwide norm in Taiwan. Thus, 17 students were included in the study.

Materials

The experimental material was an illustrated science text rewritten from a fifth-year science textbook used in Taiwan (Huang, 2013). The topic of the article was the forms and functions of flower, fruit, and seed, consisting of a text with 400 Chinese words and two illustrations (see Figure 1). The text selection had three paragraphs: the first explaining plant reproduction (sexual reproduction), the second describing a flower's detailed structure (e.g., stamen, digynia, anther, thrum, ovary) and the functions of those structures, and the third describing pollination by bees. There were two types of illustration: The first, located at the top of the screen, was a representational illustration depicting the detailed structure of a flower with labels, corresponding to the descriptive text; the second, at the bottom, was a decorative illustration depicting a bee gathering flower nectar.

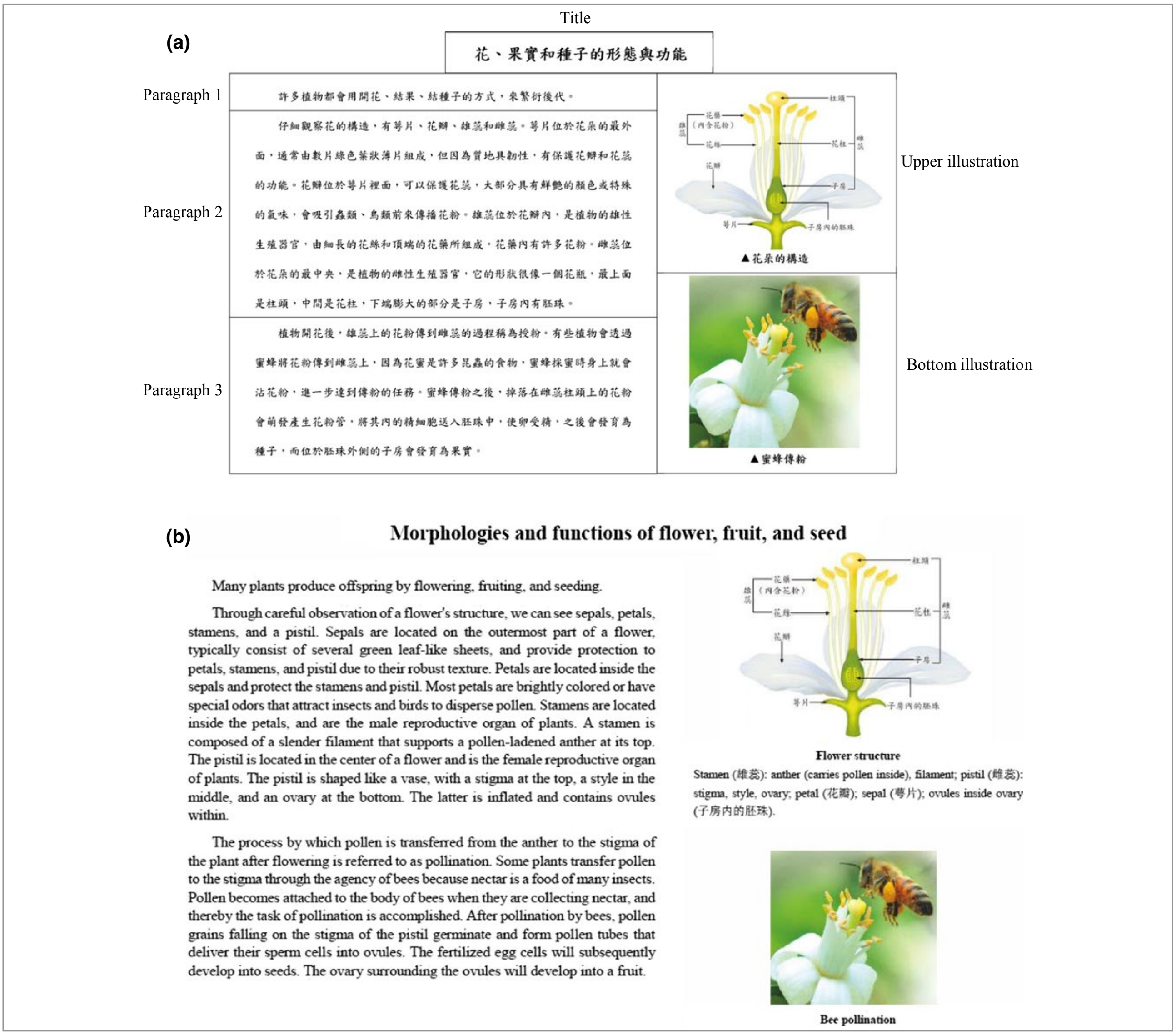
Teaching effects were avoided by using reading material from a fifth-grade textbook, as the participants in this study were fourth-grade students. This provided an opportunity to investigate the content and process of young students' learning when reading independently. The reading material was displayed on a single static computer screen, without a scroll bar or additional pages.

To assess participants' comprehension and memory of the reading material, 17 yes/no questions with three types of questions were created as a comprehension test:

1. Seven recognition items measured surface-level (characters and words) text comprehension. Participants needed to identify the correct sentence from two identical sentences with different keywords in Chinese (e.g., "Petals are <u>above</u> the sepal. Petals are <u>inside</u> the sepal. Which one appeared in the article that you read?").
2. Three textual items measured propositional formation level for reading comprehension (e.g., "Does the ovary develop into the seed?").
3. Seven illustration items measured how well the reader extracted information from the illustration (e.g., numbers or relative positions of the detailed parts of a flower) when the information was not described by the text.

The illustrated science text and the comprehension test were assessed by three experts—a PhD candidate in science education and two teachers with a master's degree in science education for teaching science courses in

FIGURE 1
The Reading Material (a) as Presented to the Participants in Chinese and (b) the English Version



Note. Six areas of interest (title, paragraph 1, paragraph 2, paragraph 3, upper diagram, and bottom diagram) of the reading material were divided to execute sequential analysis of eye movement data.

elementary school—for their difficulty (suitability for fourth-grade students) and readability.

Apparatus

Participants' eye movements were recorded using the EyeLink 1000 at a sampling rate of 1000 Hz. A chin bar was used to minimize head movement. Viewing was binocular, and eye movements were recorded from only the right eye. The reading material was presented on a 24″ LCD monitor with a resolution of 1920 × 1200 pixels. Each Chinese character in the text section of the reading material was 28 × 28 pixels, and the distance between the participant and the monitor was 65 cm. Thus, each Chinese character covered approximately a 1° angle on the screen. The diagram section on the screen was approximately 557 × 971 pixels. The entire reading material covered a 46° (horizontal) × 30° (vertical) visual angle on the screen. Data were recorded with Data Viewer software.

Procedure

This experiment was conducted individually for each participant. Participants were instructed to read an article for comprehension and press the space bar on a keyboard when they had finished reading to initiate the reading tests. There was no time limit for the reading procedure to ensure natural reading conditions. Therefore, participants read at their own pace. They were first asked to read a practice article on the screen and respond to a few comprehension questions. The formal experiment was conducted subsequently. A 12-point calibration and validation of eye movements was conducted for each participant. Participants were then instructed to keep their head still throughout the reading procedure. The experimental reading session lasted approximately 20 minutes.

All procedures were the same for both the university students and the elementary school students, except for the experimental locations. The university students were tested individually in an eye movement laboratory at the National Central University, and the fourth-grade students were tested individually in a quiet room in the elementary school.

Data Selection and Scoring Criterion

Eye Movements

Eye movement data from five participants were discarded due to unsuccessful eye tracker recordings (two participants) and apparent drift (three participants). Therefore, data from 29 participants (15 university students, comprising the adult group, and 14 elementary school students, comprising the child group) were included in the analyses. In addition, as in previous eye movement studies on reading diagrams, fixations shorter than 100 ms were excluded (Andrews, Miller, & Rayner, 2004; Jian et al., 2014; Jian & Wu, 2015), amounting to approximately 4% and 5% of fixations for the adult and child groups, respectively.

Several eye movement indicators, each reflecting different types of cognitive processing, were selected according to previous studies on diagram or text-and-diagram reading (Cook, Wiebe, & Carter, 2008; Hannus & Hyönä, 1999; Hegarty, 1992; Jian et al., 2014; Jian & Wu, 2015; Johnson & Mayer, 2012; Mason et al., 2013). The following indicators were included in the analyses:

- Total reading time (the sum of all fixation durations on an area of interest [AOI]), indicating the overall difficulty and the degree of cognitive effort required to process the reading material
- Proportion of fixation durations (the fixation duration on specific AOIs divided by the total fixation duration during the learning episode), reflecting selective attentional focus on specific target regions during learning
- Number of saccades between text and illustration (the number of times the participant moves eye fixation from text to illustration or vice versa), reflecting inference and integration of information between text and illustration

In addition to these eye movement indicators, I examined the sequence of eye fixations to investigate reading strategies adopted by the child and adult participants. A series of matrix calculations was carried out for this analysis: (1) first-pass transitions (the proportion of first fixations transferred from the initial AOI to the subsequent transfer areas), reflecting initial processing of the target AOI; and (2) total-pass transitions (the proportion of total fixations transferred from the starting AOI to the subsequent transfer areas), reflecting late processing and higher order cognitive processing during reading. This statistical method is frequently used to investigate moment-to-moment behavioral sequences (Bakeman & Gottman, 1997) and has recently been used to analyze eye movement data (Cook, Wiebe, & Carter, 2008; Jian et al., 2014).

Comprehension Test

The comprehension test included recognition, textual, and illustration items, all of which were in a dichotomous yes/no format. Each correct answer was awarded 1 point, and correct scores were transformed to percentage scores. The time taken to complete the comprehension test was also reported.

Results

Learning Outcomes

To understand differences in learning outcomes for the illustrated science text reading task among child and adult readers, independent *t*-tests were performed. The two dependent measures for learning outcomes were accuracy and reaction time. These results are shown in Table 1.

TABLE 1
Accuracy and Response Time on the Reading Test for the Child and Adult Groups

	Child group (*N* = 14)		Adult group (*N* = 15)		
	M	*SD*	*M*	*SD*	*t*-value
Accuracy on recogition items (%)	77	14	88	9	−2.41*
Accuracy on textual items (%)	72	26	96	12	−3.29**
Accuracy on illustration items (%)	74	17	85	9	−2.10*
Response time (sec)	186.86	55.54	123.67	25.64	−3.89**

Note. *M* = mean; *SD* = standard deviation.
*$p < .05$. **$p < .01$.

Compared with the adult group, the child group had significantly lower accuracies on recognition items, $t(27) = -2.41$, $p < .05$, Cohen's $d = -0.95$; textual items, $t(27) = -3.29$, $p < .01$, Cohen's $d = -1.20$; and illustration items, $t(27) = -2.10$, $p < .05$, Cohen's $d = -0.81$. As for time taken to complete the comprehension test, the child group took significantly longer than the adult group, $t(27) = 3.89$, $p < .01$, Cohen's $d = 1.46$.

Eye Movement Analysis

To investigate processing differences between the child and adult readers in reading an illustrated science text, including visual attention distribution for text and illustration, reference to relevant parts of the text and illustration, and reading pathways, eye movement indicators were examined and independent samples *t*-tests conducted. I used Cohen's benchmarks for effect size (Cohen's *d*): small (0.2), medium (0.5), and large (0.8) effects.

Whole-Article and Detailed Component Analyses

The three dependent measures for analyzing eye movements were total reading time, proportion of fixation duration, and number of saccades between text and illustration. I first took the entire article as an AOI and then divided it into four AOI sections: title, text, upper illustration, and bottom illustration. Means and standard deviations for eye movement analyses are presented in Table 2.

For the whole-article analysis, the result showed that compared with the adult group, the child group had a significantly longer total reading time, $t(27) = 3.98$, $p < .001$, Cohen's $d = 1.41$. For the detailed components of the illustrated science text, the results showed that the child group spent a significantly longer total reading time on the text section, $t(27) = 3.90$, $p < .01$, Cohen's $d = 1.42$. However, total reading time did not differ significantly across both groups for the title, upper, and bottom illustration

TABLE 2
Means (*M*s) and Standard Deviations (*SD*s) for Eye Movement Measures for the Child and Adult Groups on the Science Illustrated Text

	Child group (N = 14)		Adult group (N = 15)		
Area of interest	*M*	*SD*	*M*	*SD*	*t*-value
Whole article					
Total reading time (sec)	156.13	63.02	88.41	24.96	3.98***
Title section					
Total reading time (sec)	0.90	0.88	1.02	0.95	−0.37
Proportion of fixation duration (%)	0.5	0.5	1.1	1.0	−1.20
Text section					
Total reading time (sec)	129.06	62.30	63.82	18.24	3.90**
Proportion of fixation duration (%)	80	12	72	8	2.30*
Number of saccades between text and illustration	7.87	5.91	12.44	7.19	−2.55*
Upper illustration section					
Total reading time (sec)	22.73	11.9	21.81	9.95	0.23
Proportion of fixation duration (%)	16	10	24	8	−2.50*
Number of saccades between text and upper illustration	5.40	4.42	10.69	6.06	−2.76*
Bottom illustration section					
Total reading time (sec)	3.44	3.93	1.76	1.07	1.66
Proportion of fixation duration (%)	2	3	2	1	0.57
Number of saccades between text and bottom illustration	2.47	2.36	1.75	1.53	1.01

Note. *M* = mean; *SD* = standard deviation.
*$p < .05$. **$p < .01$. ***$p < .001$.

sections, *ps* > .05. The child group had a significantly larger proportion of fixation duration on the text section, $t(27) = 2.30$, $p < .05$, d = Cohen's 0.78; and a significantly smaller proportion of fixation duration on the upper illustration section, $t(27) = -2.50$, $p < .05$, Cohen's $d = -0.88$. However, both groups did not significantly differ in the proportion of fixation duration for the title or bottom illustration sections, *ps* > .05. Compared with the adult group, the child group had significantly fewer saccades between text and illustrations, $t(27) = -2.55$, $p < .05$, Cohen's $d = -0.69$; and between text and upper illustration, $t(27) = -2.76$, $p < .05$, Cohen's $d = -1.00$; but not for the bottom illustration, $p > .05$.

Overall, it was not surprising to find that the fourth graders needed more time to process the illustrated science text, especially for the text section. However, it was interesting to find that they paid less visual attention to the upper (representational) illustration, with a lower proportion of fixation duration. Counterintuitively, the young students were less attracted to the illustration than the words. This result indicated that the university students were more likely to use important illustration information for reading comprehension, as the younger students' diagram literacy appeared to still be developing.

Analyses of Eye Fixation Sequences

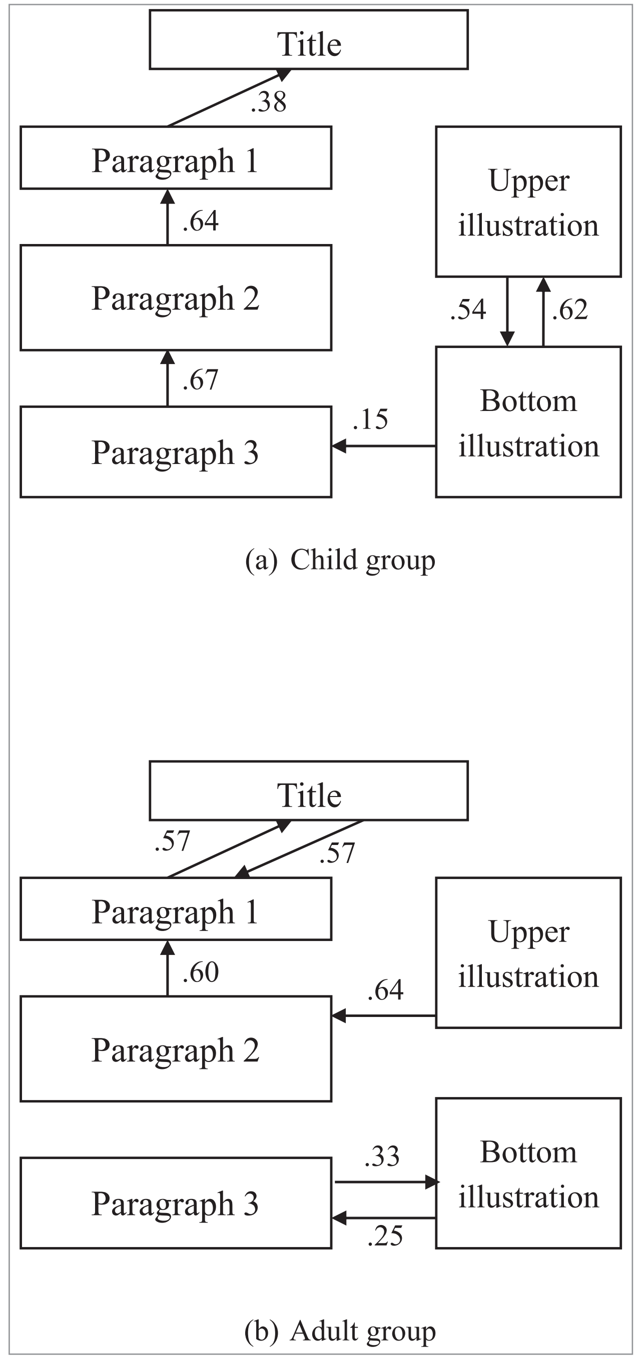
To examine cognitive processes and reading strategies of both groups, I carried out a series of sequential analysis matrix calculations (Bakeman & Gottman, 1997) for eye fixations. I divided the illustrated text into six AOIs: the title, paragraph 1, paragraph 2, paragraph 3, upper diagram, and bottom diagram (see Figure 1).

I first calculated the fixation transition from each of the six AOIs to others in the illustrated text. The adjusted residuals are shown in Appendixes A and B. The rows represent the starting AOI, and the columns represent the subsequent transfer AOIs. A *Z*-value greater than 1.96, 2.58, and 3.36 indicated that the transfer sequence reached the $p < .05$, $p < .01$, and $p < .001$ cutoff levels for statistical significance, respectively. The results for both groups' first-pass and total pathways are subsequently reported. The first-pass pathway reflects initial processing, and the total pathway reflects late processing and higher order cognitive processing.

First-Pass Fixation Sequences for Both Groups

The first-pass transition diagrams for the child and adult groups are presented in Figure 2. The *Z*-value matrix is shown in Appendix A. I found that both groups had clear differences in reading paths for the first-pass reading sequences.

FIGURE 2
First-Pass Transition Diagrams for the Child and Adult Groups



Note. The numbers beside the arrow indicators show the transition probabilities.

The child group had three reading characteristics, as shown in Figure 2a. First, the fourth graders tended to locate their fixations on each paragraph of the text and then regress to the previous paragraph (e.g., paragraph 2 to paragraph 1, paragraph 3 to paragraph 2) after leaving the target area. The transfer probability of paragraph 1 to title was significantly higher than those of other AOIs, $Z = 2.94$, $p < .01$; that of paragraph 2 to paragraph 1 was significantly higher than those of other AOIs, $Z = 2.89$, $p < .01$; and the transfer probability of paragraph 3 to paragraph 2 was significantly higher than that of other AOIs, $Z = 2.52$, $p < .05$. Further, the child group tended to refer from the diagram to the text after leaving the target area, but this tendency was unidirectional, not very clear, and only evident on the transfer from the bottom diagram to paragraph 3, $Z = 2.69$, $p < .01$. Moreover, after the first scan, the child group tended to transfer fixations back and forth between the two illustrations. Thus, the transfer probability of upper diagram to bottom diagram was significantly higher than those of other AOIs, $Z = 3.63$, $p < .001$; and the reverse, the transfer probability of bottom diagram to upper diagram, was also significantly higher than those of other AOIs, $Z = 3.31$, $p < .01$.

The adult group had very different reading characteristics from the child group, as shown in Figure 2b. First, the adult group tended to go back and forth between the title and paragraph 1. The transfer probability of title to paragraph 1 was significantly higher than those of other AOIs, $Z = 2.52$, $p < .01$. The reverse, the transfer probability of paragraph 1 to title, was also significantly higher than those of other AOIs, $Z = 3.91$, $p < .001$. Second, unlike the child group, the adult group referred to text and illustration very often during the first-pass reading. The transfer probability of upper illustration to paragraph 2 was significantly higher than those of other AOIs, $Z = 2.53$, $p < .05$. The transfer probability of bottom illustration to paragraph 3 was significantly higher than those of other AOIs, $Z = 3.73$, $p < .001$. The reverse, the transfer probability of paragraph 3 to bottom illustration, was also significantly higher than those of other AOIs, $Z = 3.01$, $p < .01$.

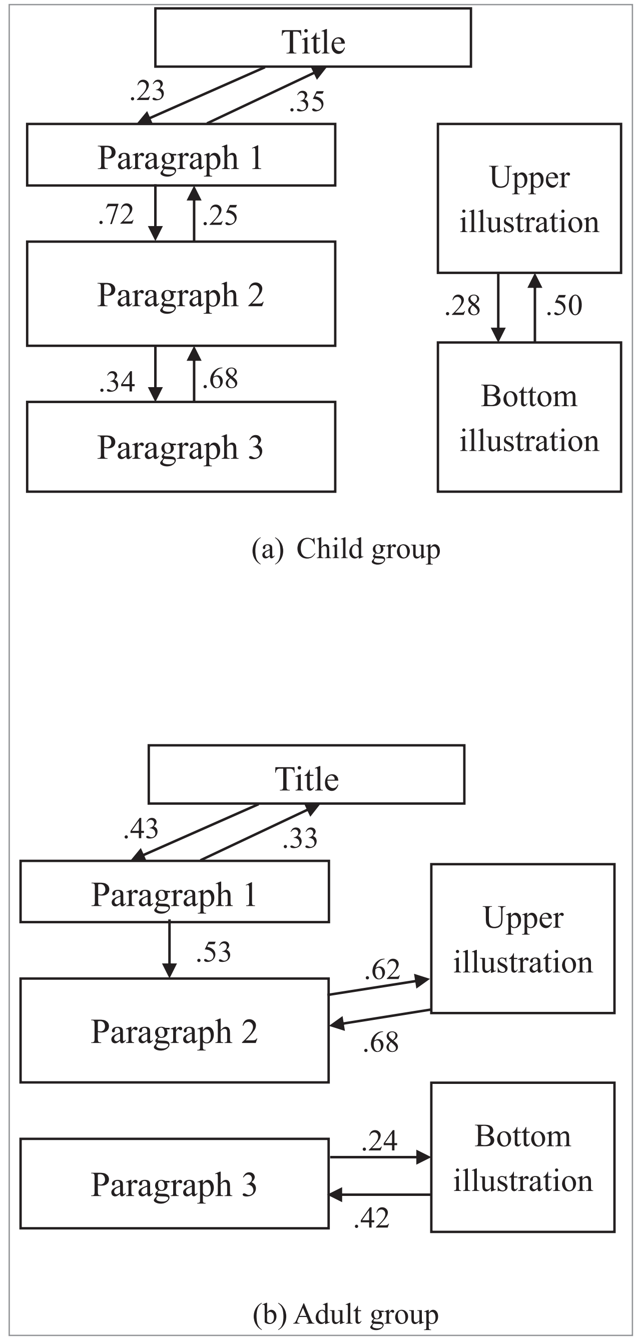
Total-Pass Fixation Sequences for Both Groups

Figure 3 presents total-pass transition diagrams for the child and adult groups. The Z-value matrix is shown in Appendix B.

The child group had very different pathways from the adult group for the total-pass reading, as shown in Figure 3a. The child group reread each paragraph several times and was more interactive for each paragraph in the text section during the total-pass reading. Transfer probabilities of title to paragraph 1, $Z = 2.88$, $p < .01$; and for paragraph 1 to title, $Z = 6.59$, $p < .001$, were higher than those of other AOIs. Transfer probabilities of paragraph 1 to paragraph 2, $Z = 5.27$, $p < .001$; and its reverse, paragraph 2 to paragraph 1, $Z = 2.19$, $p < .05$, were higher than those of other AOIs. Also, transfer probabilities of paragraph 2 to paragraph 3, $Z = 3.09$, $p < .01$; and in reverse, paragraph 3 to paragraph 2, $Z = 5.28$, $p < .001$, were higher than those of other AOIs. The two groups also tended to transfer fixations back and forth between the two diagrams, $Z = 3.68$, $p < .001$; and $Z = 4.18$, $p < .001$, respectively.

The adult group had a similar pathway in the first- and total-pass readings, as shown in Figure 3b. The

FIGURE 3
Total-Pass Transition Diagrams for the Child and Adult Groups



Note. The numbers beside the arrow indicators show the transition probabilities.

older readers would refer to the relevant parts of text and illustration more often; that is, paragraph 2 was related to upper illustration, and paragraph 3 was related to bottom illustration. The transfer probability of paragraph 2 to upper illustration was significantly higher than those of other AOIs, $Z = 4.25$, $p < .001$. The reverse, the transfer probability of upper illustration to paragraph 2, was also significantly higher than those of other AOIs, $Z = 5.97$, $p < .001$. The transfer probability of paragraph 3 to bottom illustration was significantly higher than those of other AOIs, $Z = 5.25$, $p < .001$. The reverse, the transfer probability of bottom illustration to paragraph 3, was also significantly higher than those of other AOIs, $Z = 4.92$, $p < .001$.

Overall, the child and adult groups demonstrated very different reading paths while reading the illustrated science text both in the first- and total-pass readings. The younger readers rarely linked the information between multiple representations of text and illustration but focused on information within one representation of text or illustration. However, the older readers related the information between multiple representations of text and illustration very often but seldom reread information within the text paragraphs. Moreover, this study had two interesting findings. Both groups were aware that the relation between title and paragraphs was crucial for reading comprehension, so they reread the tile and paragraph 1 very often. Further, because the fourth-grade readers had a high reading comprehension ability, they were able to monitor their reading comprehension and developed a rereading strategy when their reading comprehension suffered. This is supported by their significantly higher transition scores within each of the three paragraphs. Adults did not perform rereading sequences, as the article—selected from a fifth-grade science textbook—was easy to comprehend.

Discussion

The present study investigated learning strategies involved in reading an illustrated biology text among fourth-grade students with high reading ability and adult readers. I was interested in examining not only the conscious cognitive processes operating when reading illustrated science texts but also the automatic, unconscious learning outcomes.

An important advancement of this study was that I attempted to overcome the limitations of previous research. First, I used eye-tracking technology and sequential analysis as statistical methods to investigate young readers' cognitive processes and reading strategies when reading illustrated scientific texts. Previous research on reading illustrated texts that used eye tracker technology drew inferences about cognition from measurements of fixations (e.g., total reading time) or locations (e.g., proportion of fixations on AOIs; Hannus & Hyönä, 1999; Mason et al., 2013). In the present study, I analyzed these indicators in addition to sequences of eye fixations by conducting sequential analyses of transition probabilities from all AOIs (title, paragraph 1, paragraph 2, paragraph 3, upper diagram, and bottom diagram) in relation to each other. This method was identical to my prior research (Jian et al., 2014), using multiple eye movement indicators and sequential analysis of eye fixations to provide convergent evidence to infer the nature of cognitive processing when reading illustrated texts. Second, this study provided diagrammatic illustrations to evaluate graphic memory and comprehension, making substantial contributions to the graphic reading research domain. Few previous studies used comprehension tests designed specifically to evaluate graphic memory or comprehension (Hannus & Hyönä, 1999; Mason et al., 2013). Moreover, none had made a detailed inquiry of processes involved in reading illustrated text among young students.

As predicted by hypothesis 1 (on the effect of illustration on text reading and comprehension), I found that university readers emphasized the role of illustration more than the fourth-grade students did. In particular, for the representational illustration, the former paid more visual attention to the representational illustration and referred to both representations of text and illustration more frequently to remember and comprehend science concepts conveyed in the article. This conclusion is supported by the higher proportion of fixation durations on the representational illustration, more saccades between text and illustration, and better scores on all items (recognition, textual, and illustration) in the reading comprehension test obtained by the university readers, as compared with the fourth-grade students. The finding that young students seldom use illustrated information for reading comprehension was similar to previous findings. When using eye-tracking technology, Hannus and Hyönä (1999) found that regardless of ability, fourth-grade readers only spent approximately 6% of fixation durations on several illustrations accompanying the article on biology. Similarly, compared with studies using think-aloud protocols (Moore & Scevak, 1997; Norman, 2012), Moore and Scevak found that fifth-grade students focused on detailed information in the text but seldom read visually represented information in the illustrated science text. Further, Norman showed that even for high-ability young readers, behaviors of viewing diagrams or illustrations and reading comprehension were apparently unrelated. These studies implied that diagram literacy typically shows slower development than word recognition abilities (Kress & van Leeuwen, 1996; McTigue, 2009; McTigue & Flowers, 2011).

As predicted by hypothesis 2 (on reading strategies and cognitive processes of text and illustration comprehension), I confirmed that the younger and older readers demonstrated different cognitive processes. The results of transition probabilities and sequential analyses of eye fixations showed that whereas university students demonstrated bidirectional reading pathways between text and illustrations in both the first- and total-pass reading stages, the fourth-grade students demonstrated unidirectional reading pathways using only one representation, either text or illustration. Adult readers were capable of selecting, organizing, and integrating relevant information from the text and graphics to finally construct a coherent mental representation of the illustrated text. However, fourth-grade students were unable to link information from both text and illustration representations to aid concept acquisition. This may be because the fourth graders' reading strategies were not mature enough to perceive the connections between the information in the text and the diagram that are crucial for constructing multiple representations in their mental model. This implies that the principles of multimedia learning (Mayer, 2005) and the text and picture comprehension theory (Schnotz & Bannert, 2003) cannot be generalized to young readers. This conclusion is consistent with McTigue's (2009) findings.

Furthermore, on comparing first- and total-pass pathways for both groups, I found interesting and unique characteristics. The adults' reading strategies were very stable from the beginning to later reading stages, whereas the fourth graders demonstrated variable reading strategies between the two reading stages. Moreover, the adult readers were capable of using relevant information from the text and illustration at both the first- and total-pass reading stages. The university students went back and forth between the second paragraph, which described the parts of a flower and its functions, and the upper illustration, which depicted the structure of a flower, to understand the parts of a flower and the functions of each component. These readers also went back and forth between the third paragraph and the bottom illustration to understand bee pollination. The adult readers recognized that the relation between the title and the text was important, as evidenced by their repeated eye movement patterns between the title and the first paragraph at both reading stages.

In contrast, for the fourth-grade students, the reading strategy differed between stages. The first-pass reading stage reflected initial processing, and the total-pass reading stage reflected late processing and higher order cognitive processing during reading (Jian et al., 2014; Mason et al., 2013). The most apparent characteristic was that at the first-pass reading, they tended to fixate on each paragraph of the text and then regress to the previous paragraph after leaving the target area (e.g., paragraph 1 to title, paragraph 2 to paragraph 1, paragraph 3 to paragraph 2); however, at the total-pass reading, they went back and forth between only contiguous paragraphs, with no jumps from the third to the first paragraph or the reverse. This regression to a previous paragraph indicates that the young readers may have been aware that they did not understand the text or were attempting to integrate previous information with the present text (Rayner, 1998). These findings suggest that the young participants with high reading ability in this study monitored their reading comprehension from the beginning to late reading stages but organized the partial pieces of detailed information between paragraphs into a sophisticated concept only in the late processing stage (Kintsch & van Dijk, 1978).

Despite differences in cognitive processes between older and younger readers, high-ability young readers still have skill in reading comprehension. For example, young readers looked back to previous paragraphs, indicating that they were monitoring their comprehension status. Further, young readers spent a similar reading time on the title and illustration sections compared with adult readers. This suggests that high-ability fourth graders can pay attention to important parts of illustrated text but that the distribution of text and illustration attention differed between groups. Moreover, although older readers outperformed younger readers on all reading test items, the accuracy of recognition items, textual items, and illustration items reached 72–77% in the fourth graders. This indicates that high-ability fourth-grade readers still gained some science knowledge from reading the article.

Conclusions, Implications, and Limitations

According to the cognitive theory of multimedia learning (Mayer, 2005), to successfully acquire new science knowledge by reading illustrated texts, a reader needs to decode, organize, and integrate the multiple representations of verbal and graphical information. Particularly in science reading, students are frequently exposed to visual displays of information in textbooks and popular science articles (Cook, 2006; Ferk et al., 2003; Pozzer & Roth, 2003; Slough et al., 2010). The present study demonstrated that the fourth-grade students relied more on text information rather than the illustration to learn scientific knowledge regarding a flower's structure, function, and pollination. Therefore, I found that the visual literacy of fourth-grade readers for science illustrations was limited.

This study had several implications for the disciplinary literacy debate and for education. First, there is a hot debate (Collin, 2014) on how to teach content area literacy at present, a strategies approach versus a disciplinary approach. The former focuses on general practices of reading and writing, emphasizing continuities across content areas and promoting common strategies for literate work in different subjects, and the latter attunes to the particular discourse of particular domains, emphasizing the ability to read like a scientist. Although the present study did not solve the debate, few participants in that debate have studied how different kinds of science texts ask students to process print and pictorial information in different ways. From the observation of the young participants' eye movements, my viewpoint was consistent with Collin's and with Fagella-Luby, Graner, Deshler, and Drew's (2012). I do not think that most young readers are capable of reading or thinking like scientists, even when receiving formal diagram literacy instruction.

Second, because the younger students in the present study had a lower proportion of fixation duration than did the adult readers, this suggests that teachers should encourage elementary school students to spend more time on reading important illustrations to grasp whole–part spatial relations to deepen the representation preserved in their mental image. Third, young readers seldom refer to both representations of text and illustration, which may partially explain why their learning outcomes for scientific knowledge were poorer than that of adult readers. Teachers should deliberately train their elementary school students to notice relevant relations between text and illustration and combine both verbal and pictorial representations to remember and comprehend scientific information better, as suggested by the dual coding theory (Paivio, 1990).

In Taiwan's elementary schools, most teachers are not aware of the importance of diagrams and do not emphasize teaching their students how to read diagrams. Instead, teachers rely on text information to explain scientific concepts to their students. However, most articles consist of multiple representations, both verbal and pictorial. Therefore, developing diagram literacy instruction in conjunction with printed text comprehension for young readers is an important and urgent goal in reading instruction. For example, teachers modeling their thinking processes are an effective method of instruction for young students to learn a new reading skill (Brown, Palincsar, & Armbruster, 2004). Further research on science reading involving illustrated text can investigate how the teacher's modeling behavior for selecting, organizing, and integrating both text and illustration can change young students' cognitive processes and reading strategies for comprehending illustrated text, which in turn could promote young readers' abilities to read for learning new scientific knowledge and concepts.

Further, consideration of how to construct texts for elementary-age children is another way to improve young readers' diagram literacy. Scheiter and Eitel (2015) found that designed signals for semantically relevant information from the text and diagram sections in illustrated science texts benefited undergraduate readers in their integration of information from text and diagram elements. Further research should investigate whether this facilitation has the same effect for young readers. For example, design signals in the text should refer to the relevant diagram section (e.g., the same color marked on the words in the text and its relevant concept on the diagram section). Then, we could examine whether this influences young readers to reference illustrations and their relevant concepts within the text more frequently and, ultimately, whether this benefits learning outcomes.

Although this study provided theoretical and research contributions, as mentioned previously, it also had some limitations, which future research should address. First, this study found that diagram literacy seems to develop more slowly as compared with word recognition abilities. This phenomenon is consistent with previous research (Kress & van Leeuwen, 1996; McTigue, 2009; McTigue & Flowers, 2011). However, this study was limited in that I could not determine whether this was due to young readers being incapable of doing it at the fourth-grade reading level or a result of not receiving formal instruction on comprehending diagrams prior to fourth grade. Future research can design an experiment manipulating diagram literacy instruction to address this question.

Second, I did not design integrative items for measuring readers' integration of written textual material with the illustrations. Therefore, it was difficult to assess the degree to which young readers' lesser movements between written text and illustrations negatively affected their comprehension. Future research can add these test items (using either yes/no items or essay questions) to measure the degree to which participants integrate textual and pictorial information while reading an article.

Third, this study did not control domain knowledge of the participants, and it is reasonable to assume that the college students had considerably higher domain knowledge relevant to the text than did the fourth-grade students, whose curriculum had not yet covered this fifth-grade topic. Therefore, I cannot determine whether adult–child differences in this case were true developmental differences in graphics processing, differences in domain knowledge, or some combination of both. Future research can design an experiment to confirm the cause of this effect. For example, to confirm whether the adult–child differences were due to developmental differences in graphics processing, future research can design two different reading materials for adult readers and child readers, ensuring that both articles are unfamiliar or unlearned for both groups. In contrast, to confirm whether the adult–child differences were due to differential domain knowledge about the reading material, future research should include fourth-grade readers with high and low domain knowledge about the reading material.

Finally, only an article on biology was used as the reading material, so we must exercise caution in generalizing the findings to the reading of multiple texts on other scientific topics. Further research should use different scientific topics to investigate the generalizability of the findings.

NOTE

This research was supported by a grant from the Ministry of Science and Technology in Taiwan (MOST103-2511-S-003-065-MY3).

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Submitted February 20, 2015
Final revision received July 31, 2015
Accepted August 3, 2015

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APPENDIX A

Z-VALUE Matrix of the First-Pass Sequences for the Child and Adult Groups

Target area of interest (AOI)						
Starting AOI	**Title**	**Paragraph 1**	**Paragraph 2**	**Paragraph 3**	**Upper illustration**	**Bottom illustration**
Child group						
Title	—	1.86	−1.96	−0.69	1.51	−1.73
Paragraph 1	2.94**	—	1.55	−0.73	−1.52	−1.83
Paragraph 2	1.56	2.89**	—	−0.65	−1.96	−0.78
Paragraph 3	−1.44	−2.26	2.52*	—	−1.37	0.71
Upper illustration	−1.52	−0.41	−0.91	−0.73	—	3.63***
Bottom illustration	−1.52	−1.73	−1.52	2.69**	3.31**	—
Adult group						
Title	—	2.52*	−1.62	−0.97	−0.02	−0.48
Paragraph 1	3.91***	—	0.75	−0.97	−2.10	−1.41
Paragraph 2	0.79	2.84**	—	−1.02	−0.86	−1.48
Paragraph 3	−2.03	−2.61	−0.08	—	1.15	3.01**
Upper illustration	−0.47	−1.86	2.53*	−0.97	—	0.45
Bottom illustration	−2.13	−0.98	−1.42	3.73***	1.58	—

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

APPENDIX B

Z-VALUE Matrix of the Total-Pass Sequences for the Child and Adult Groups

Target area of interest (AOI)						
Starting AOI	**Title**	**Paragraph 1**	**Paragraph 2**	**Paragraph 3**	**Upper illustration**	**Bottom illustration**
Child group						
Title	—	2.88**	−2.37	−0.95	1.86	−0.82
Paragraph 1	6.59***	—	5.27***	−3.70	−3.15	−2.70
Paragraph 2	−2.05	2.19**	—	0.92**	−0.42	−3.64
Paragraph 3	−1.92	−3.22	5.28***	—	−2.71	1.07
Upper illustration	−1.50	−2.17	0.88	−1.00	—	3.68***
Bottom illustration	−1.52	−2.40	−2.62	1.30	4.18***	—
Adult group						
Title	—	5.93***	−1.33	−1.77	−1.12	−0.22
Paragraph 1	9.15***	—	2.56**	−2.72	−3.46	−2.20
Paragraph 2	−2.61	0.61	—	−2.10	4.25***	−4.92
Paragraph 3	−1.87	−2.76	0.39	—	0.00	5.25***
Upper illustration	−3.16	−4.67	5.97***	−1.07	—	0.43
Bottom illustration	−1.51	−0.61	−2.21	4.92***	−0.23	—

$^{**}p < .01$. $^{***}p < .001$.