Utilization of Illustrations during Learning of Science Textbook Passages among Low- and High-Ability Children

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Effects of illustrations on learning authentic textbook materials were studied among 10-year-old elementary school children of high and low intellectual ability. Experiment 1 showed that the presence of illustrations improved learning of illustrated text content, but not that of nonillustrated text content. Comprehension scores were improved by the presence of illustrations for high-ability children, but not for low-ability children. In Experiment 2, children’s eye movements were measured during learning of illustrated textbook passages to study how children divide their attention between text and illustrations. The results suggest that learning is heavily driven by the text and that children inspect illustrations only minimally. High-ability students were more strategic in processing in the sense that they spent relatively more time on pertinent segments of text and illustrations. It is concluded that the learning of illustrated science textbook materials involves requirements that may be more readily met by more intellectually capable students.

Illustrations are an integral part of modern instructional textbooks. They are assumed to serve a number of functions in the learning process and to bring about general enhancement in learning outcomes. Levie and Lentz (1982) distinguish four general functions of illustrations (see also Peeck, 1987): (1) attention guiding, (2) affective, (3) cognitive, and (4) compensatory functions. In serving the attention guidance function, illustrations are assumed to attract learners to pay more attention to the materials in general and to the illustrated contents in particular. Developing interest in and motivation toward textbook materials are typical affective functions that illustrations are assumed to possess. As cognitive functions, textbook illustrations are expected to improve learning by enhancing comprehension and memory for instructional materials. Learning benefits are believed to result from deeper and more effortful processing of text contents in the presence of illus-

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Illustrations are further assumed to bring about multiform mental representations of the instructional materials, which will help later recall of the contents (e.g., Paivio & Csapo, 1969). Finally, the compensatory function of illustrations proposed by Levie and Lentz (1982) refers to the assumption that the learning achievement of poor readers is benefited more by the presence of illustrations than is that of more skilled readers.

In their excellent review of the literature on the effects of text illustrations, Levie and Lentz (1982) conclude that the vast majority of studies comparing illustrated text to text alone has observed a significant positive effect of illustrations on learning illustrated text information, that is, information that was conveyed both in illustrations and in text. On the other hand, illustrations have not been found to influence the learning of nonillustrated text information, that is, information that is conveyed in text only. Thus, there is abundant evidence showing that illustrations induce specific learning benefits, but these benefits appear to be restricted only to illustrated text information.

There may be several reasons why text illustrations enhance learning outcomes for illustrated text content. One possibility is offered by the research on human memory, where it is well established that memory for to-be-learned materials is improved if both a verbal and a pictorial representation can be constructed of the stimuli. For example, words are better recalled when a mental image is created of the word’s denotative meaning (Paivio & Csapo, 1969). Employing Paivio’s (1986) dual-coding theory in the process of learning instructional materials, it can be assumed that memory for illustrated text will become richer in detail than will memory for materials consisting of text alone. This notion is based on the idea that illustrated texts encourage learners to construct not only propositional representations based on written materials but also pictorial representations with the help of illustrations. The more elaborate representation can subsequently be consulted when some aspect of the textbook content needs to be retrieved from memory (see also Kulhavy, Stock, Verdi, Ritschoff & Savenye, 1993, for a similar argument for learning a geographic text accompanied by a map). As another possible explanation, it may be assumed that when similar information is provided, both verbally and pictorially more elaborate semantic processing will ensue, resulting in better comprehension and memory of the illustrated text content (cf. the “levels of processing” notion suggested by Craik & Lockhart, 1972).

Some researchers (e.g., Williams, 1968) have suggested that the presence of illustrations brings about increased motivation and more elaborate processing of the whole text content and not only of illustrated text content, which would then lead to a general improvement in learning. However, as we pointed out above, most studies reviewed by Levie and Lentz (1982) do not support this claim. In contrast, the available evidence strongly suggests
that to obtain improvement in learning, illustrations need to be directly relevant to some aspect of the text content.

More recently, research has concentrated on disentangling the relevant conditions needed to obtain illustration benefits in learning (e.g., Mayer, 1989; Mayer & Gallini, 1990; Peeck, 1993) and the underlying reasons for these beneficial effects (e.g., Kulhavy et al., 1993). Characteristics of learners (e.g., reading ability, reasoning ability, prior knowledge) and learning materials (e.g., text difficulty, the presence or absence of color in illustrations, etc.) have been considered as well as the nature of the learning activities (e.g., verbatim retention, problem solving, comprehension) in enhancing illustration benefits. In the present study, we examined the effects of learner characteristics on the utilization of illustrations during learning. Second, we wanted to make a more detailed look at the learning process by registering learners’ eye movements during the learning phase. In Experiment 1, 10-year-old children with different intellectual abilities were asked to study 2-page biology textbook passages, both illustrated and nonillustrated, in order to be able to comprehend and memorize as much of the contents as possible. In Experiment 2, a subgroup of low and high ability 4th grade students were given another set of illustrated textbook passages to study while their eye movements were recorded. Eye-tracking is an optimal measure to study attention guidance, as eye fixation patterns yield an on-line record of the learning process by providing information about where learners visually attend in the textbook passages and for how long they inspect different sections. In Experiment 2, we were particularly interested in seeing how much attention low and high ability students pay to illustrations and how students divide their attention between text and illustrations (additional results can be found in Hannus, 1996).

Textbooks as Learning Materials

In the vast majority of studies examining the effects of illustrations, text is typically accompanied by only one illustration. This is not the case with authentic textbook materials, however. The authentic textbook materials used in the present study all contained more than one illustration per passage. Similarly, Willows, Borwick, and Hayvren (1981) note that in American first-grade primers, there is typically more than one illustration per page and illustrations cover a clearly larger area of the page than text. Thus, the immediate learning environment faced by children in a school setting is qualitatively quite different from that of a typical scientific study. With authentic illustrated textbooks, children constantly need to make decisions as to which picture they should attend to and which picture they ought to ignore, when to study each picture and what information they should extract from each picture, etc. Thus, it is not totally clear to what extent facilitatory effects of
Illustrations obtained using single-picture presentations extend to illustrated textbook materials used in school environments.

Illustrated textbook materials can be regarded as highly complex stimulus environments for several reasons. To build a coherent mental representation of all information conveyed in an illustrated text passage, the child has to gather both verbally and pictorially presented information from different sections of the page and integrate them into a coherent whole. To accomplish this, the child should decide in which order to study the materials, in other words, which segments are linked together in content. This may prove particularly demanding if the text gives no explicit signals for an optimal study sequence (e.g., a reference in text to a relevant illustration). Finally, extracting information from science textbook illustrations can be a major intellectual challenge to a young learner. These illustrations are seldom readily interpretable as such, but often require considerable mental effort from the learner. For example, the elementary school biology textbook used in the present study contains a 4-picture illustration depicting the development of a frog from an egg to an adult individual. To fully understand the biological principle governing this transformation, the child needs to pay particular attention to relevant features in the photographs, which may prove quite difficult, especially without consulting the corresponding text material.

Learner Characteristics

We argue above that studying illustrated science textbook materials can be quite a challenge to a child and calls for considerable intellectual capabilities. To successfully comprehend an illustrated science passage, the child is required (1) to comprehend often very abstract and difficult concepts and principles described in text and/or in illustration, (2) to decide in which sequence text and illustrations are studied, (3) to distinguish between pertinent and less pertinent information in text and in illustrations, (4) to decide which pieces of information (such as text paragraphs and illustrations) are related to each other and converge on the same concept/principle, and (5) to integrate related pieces of information into a coherent internal representation. A successful execution of the above type of cognitive processes requires good intellectual capabilities; thus, it is reasonable to assume that intellectually high-achieving children would be better equipped to carry out such integrative processes. Consequently, we expect high-ability students to make greater use of and benefit more from illustrations than do their low-ability peers.

To date, there is only little direct evidence available that bears on the relationship between intellectual ability and the use of illustrations. In compliance with our prediction, Harber (1983) observed beneficial effects of illustrations among normally achieving 2nd, 3rd and 4th grade children, but detrimental effects among disabled children of the same age. Harber (1983) interprets this to suggest that the presence of illustrations distracts learning
disabled children’s attention away from the text, thus bringing about a generally poor learning outcome. This interpretation is only suggestive, as Harber did not directly measure children’s attentional processes (e.g., their eye fixation patterns during learning).

Similarly, Reid and Beveridge (1986) showed that most able (i.e., in terms of learning success) 14-year-old secondary school children remembered significantly more information in the presence of illustrations, whereas the performance of least able students was hampered when illustrations were present. In a follow-up study, Reid and Beveridge (1990) presented illustrated text materials to the same age group using a computer program that recorded the time children spent studying the text and the illustration. They observed that less successful learners spent more time on illustrations and accessed illustrations more frequently than did their better achieving peers. Taking these two studies together, the authors suggest that the detrimental effect of illustrations on learning may be due to less able children’s frequently shifting their attention between text and illustration, which places heavy demands on integrating textual and pictorial information. By further assuming that these integration processes often fail among less able children, Reid and Beveridge are in a position to argue that the frequent back-and-forth looking between text and illustration hampers the learning process of these children.

Also generally consistent with our theorizing, Schnotz, Picard, and Hron (1993) demonstrated that successful adult learners made more use of graphic information than did less successful adult learners when studying a long text accompanied by a map of world time zones. This result was interpreted to suggest that successful learners build a more elaborate mental model of the learning materials on the basis of illustrations. In a similar vein, Mayer and Gallini (1990) suggest that low prior knowledge adult learners are helped more by illustrations than are high prior knowledge learners, because illustrations help them to build up adequate mental models, which they would not be able to do otherwise (see also Mayer, 1989).

Contrary to our prediction, however, Koran and Koran (1980) showed that 7th and 8th grade students with low reasoning ability benefited from the presence of a pictorial adjunct, whereas students with high reasoning ability performed better without a drawing. As a part of a text about the hydrological cycle, Koran and Koran (1980) employed a schematic diagram of the cycle, which was believed to provide an organizational structure about the text content and thus facilitate comprehension and recall. The finding that low-ability students were helped more by the presence of a schematic diagram was explained by the notion that low-ability learners, in contrast to high-ability students, do not spontaneously construct coherent mental structures of text materials.

To sum up, the studies employing young learners as subjects all assessed the effects of illustrations by asking the children to study illustrated and
nonillustrated materials for a subsequent comprehension or recall test. Subjects were grouped into low- and high-ability groups on the basis of their learning success in the task (Reid & Beveridge, 1986, 1990), their school achievement (Harber, 1983), or their score on a reasoning test (Koran & Koran, 1980). The studies tested 13–14-year-old students, except Harber (1983) who used younger elementary school children. Reid and Beveridge (1986) and Harber (1983) observed illustration benefits for high-ability children and detrimental effects of illustrations for low-ability children, whereas Koran and Koran (1980) found exactly the opposite pattern. It is not obvious on what this inconsistency in results is based. One may argue that the selection by reasoning ability would yield groups qualitatively distinct from those selected by learning success or school achievement. However, this is unlikely, as reasoning ability appears to be significantly related to both (see Experiment 1 for more information). Thus, at present, no firm conclusions can be made on whether they are the intellectually high-achieving or low-achieving children who benefit more from the presence of illustrations, or even whether intellectual ability plays any relevant role in determining the extent to which illustrations are utilized by elementary school-aged children. Results from studies of more mature adult learners (Mayer, 1989; Mayer & Gallini, 1990; Schnotz et al., 1993) may not be directly applicable to younger learners, because children, particularly those with poorer intellectual abilities, may not be capable of carrying out the integrative processes between text and illustrations needed to yield illustration benefits in learning.

Attentional Processes in Learning Illustrated Materials

Published research evidence in support of the attention guidance function of illustrations is meager. We know of two studies which have directly examined how illustrations influence the way learners guide their attention, that is, how much learners pay attention to illustrations and how they divide their attention between text and illustrations during the process of learning illustrated text materials. The study by Reid and Beveridge (1990) was already discussed above. The study showed that less able children spent more time on illustrations and accessed them more frequently than did their more successfully performing peers. The study of Hegarty, Carpenter, and Just (1991) registered adult subjects’ eye movements while they studied a scientific text accompanied by diagrams. The study showed, among other things, that their adult subjects frequently switched between reading the text and processing the diagram. They further showed that the text played a central role in controlling learners’ attention, in the sense that subjects usually inspected diagrams only at sentence and clause boundaries. Subjects typically inspected components of diagrams that were referred to in the sentence they just completed reading. Finally, low-spatial-ability subjects inspected a diagram more
We conducted Experiment 2 as a further attempt to examine how elementary school children divide their attention between text and illustrations during learning of scientific materials. Moreover, we were interested in finding out whether we could observe any differences between high- and low-ability students in their on-line processing of illustrated textbook materials. The two studies cited above suggest that low-ability students would spend more time in studying illustrations than would high-ability students.

EXPERIMENT 1

Experiment 1 was performed to test our prediction that illustration benefits will be greater for intellectually high-ability children than low-ability children in learning the contents of biology textbook materials. To maximize ecological validity of the experiment, it was conducted in a school environment as a part of students’ regular school schedule. This was made possible by the first author’s being the principal of the two schools chosen for the study. To further increase ecological validity, we used as stimuli authentic biology textbook materials that, at the time of the study, were used nationwide in the 4th grade in Finland. The nature of learning materials differs from that of most other studies: Levie and Lentz (1982) note that most earlier studies have used narrative passages as stimuli and very few studies have examined existing learning materials in normal classroom learning situations (but see Holliday, 1975; Holliday & Harvey, 1976).

We selected six textbook passages for the study, each passage being about a separate topic. Two versions of each textbook passage were prepared: an illustrated version and a text-alone version. In the illustrated versions, all illustrations appeared as color pictures and were representational in nature (i.e., no charts, graphs, or diagrams were included). Both drawings and photographs were used in the selected passages. The text-alone version was prepared by simply removing all illustrations from the original textbook passage. In what follows, we refer to the difference in learning performance between illustrated and text-alone versions as the illustration benefit. It should be kept in mind, however, that the effect should be attributed to the picture-text combination, not to the illustrations alone.

The entire 4th grade class of two urban elementary schools was recruited for the study. Students were grouped on the basis of their intellectual ability using the Raven Matrices Test to three clusters: low-, medium-, and high-ability students. The Raven test is shown to be a very good measure of general intellectual ability (Carpenter, Just, & Shell, 1990; Marshalek, Lohman, & Snow, 1983). According to Carpenter et al. (1990), the Raven test measures “the common ability to decompose problems into manageable seg-
ments and iterate through them, the differential ability to manage the hierarchy of goals and subgoals generated by this problem decomposition, and the differential ability to form higher level abstractions’’ (p. 429). In constructing a coherent mental representation of a difficult text accompanied by several illustrations, at least a subset of these same cognitive operations will be needed for a successful accomplishment of the task. Thus, it is not surprising that the Raven scores correlate positively with general school achievement.

We predicted high-ability students to show greater illustration benefits than low-ability students. As discussed above, this prediction is based on the idea that illustrated scientific textbook materials comprise a complex learning environment, which requires a good amount of intellectual capacity to be dealt with successfully. Low-ability students may even be distracted from the study task (cf. Harber, 1983), resulting in a poorer performance in the presence of illustrations (Reid & Beveridge, 1986). On the basis of the Koran and Koran (1980) study, exactly an opposite prediction would be made. Their study suggests that low-ability children would be the group most likely to benefit from illustrations in learning fairly demanding textbook materials in biology. The reasoning behind this competing hypothesis is that, with the help of pictorial adjuncts, low-ability children will process the materials to a semantically deeper level, which they would not do otherwise, resulting in a more elaborate and more complete internal representation of the content matter.

Learning outcomes were assessed by testing how well the children comprehended the contents of the textbook passages and how much of the contents they were able to recall immediately after the study phase. Following the conclusions of Levie and Lentz (1982), we expected the illustration benefits to show up particularly for illustrated text content and less so for nonillustrated text content.

Methods

Subjects. A total of 108 4th grade students (55 girls and 53 boys) were recruited from two elementary schools (Ilpoinen and Luolavuori) in the city of Turku, Finland. The subject pool comprised the entire 4th grade class of both schools.

Prior to conducting the learning experiment, the students were administered three sets (C, D, and E) of the Raven (1958) nonverbal intelligence test. We decided not to use the A and B sets, because pilot tests suggested that they were too easy to have much discriminating power. On the basis of the results of the Raven test, three subgroups of students were formed: high-, medium-, and low-ability students. The high-ability group included the subjects belonging to the highest quartile, the medium group the subjects belonging to the two middle quartiles, and the low-ability group the subjects belonging to the lowest quartile. The high achievers consisted of 22 students (10 girls, 12 boys), the medium group of 58 students (30 girls, 28 boys), and the low achievers of 28 students (15 girls, 13 boys). The composite score of the C, D, and E sets ranged between 27–33 for the high-ability group, between 17–26 for the medium-ability group, and between 0–16 for the low-ability group. The averages were
28.5 (SD = 1.6), 22.3 (SD = 2.8) and 10.1 (SD = 5.6) for the high-, medium-, and low-
ability groups, respectively. To make comparisons to test norms, we first transformed the
average test scores of the three groups based on the C, D, and E versions to expected total
scores with the help of the test manual (Raven, Court, & Raven, 1992). In comparison to the
British norms (Raven et al., 1992), the high-ability group scored, on average, at the 95th
percentile, the medium-ability group at the 75th percentile, and the low-ability group a little
below the 10th percentile.

We also obtained teacher assessments of children’s academic achievement in the form of
their last report card. As expected, the Raven scores correlated positively with academic
achievement: the correlation with the grand mean of school grades (the range is from 4 to
10) of the academic subjects was .38, with the grade in reading and writing .33, and the grade
in biology .31. All correlations were statistically significant (p < .05).

Learning materials. The learning materials were taken from Värikäs luonto 4 (Kara,
Koskenniemi, Kovakoski, & Nurmi, 1989), a 4th-year biology textbook used nationwide in
Finland at the time of the study. Six textbook passages were selected, each about a specific
topic (i.e., snakes, hawks, lizards, grasshoppers, ferns, and birds nesting in holes). A black-
and-white copy of an illustrated passage used in Experiment 2 is presented in Fig. 1 (the
general layout of illustrated passages used in Experiment 1 was very similar). All passages
comprised two pages that were available to the children without the need of turning the page.
The passages were selected with the idea in mind that at least some of the illustrations were
tightly linked to the text and added relevant information about the topic. The six passages
covered about 30% of the spring term’s biology course.

Two versions were created of each textbook passage: an original version consisting of text
and colored illustrations, and a text-alone version from which all illustrations were removed,
but the figure captions left in their original positions. Each illustrated passage contained 3–
5 color pictures; both drawings and photographs were used. The length of the texts varied
between 174 and 236 words with an average of 197 words. In Mayer’s terms (see, e.g.,
Mayer & Gallini, 1990), many of the illustrations were “nonexplanative,” in the sense that
they only showed a general structure of an organism (such as a fly) by illustrating and naming
the different parts (see the top left illustration in Fig. 1). Another type of nonexplanative
illustration is one in which two organisms that resemble each other are shown next to each
other to point out the discriminating features (see the bottom right illustration in Fig. 1).
There were also a few explanatory illustrations, which depict a biological function, such as
the development of a fly from an egg to an adult individual (see the top right illustration of
Fig. 1).

In the beginning of the school year, the selected textbook passages were removed from the
students’ textbook copies to assure that the learning materials were unknown to the subjects.
Moreover, around the time of the study, the biology class was replaced with geography, so
no biology was taught when the experiment was carried out.

Each subject was exposed to three original illustrated passages and three text-alone versions.
Thus, passage type was a within-subject variable. The two versions of each passage were
counterbalanced across subjects.

Test materials. To assess children’s comprehension and memory of the textbook materials,
10–11 questions were created for each passage, which were given to the subjects on a separate
sheet of paper immediately after they completed studying each passage. The questions were
of the following types: (1) students were first asked to write down a list of the most important
ideas of the passage, (2) a set of 6–8 questions was constructed for each passage about some
details mentioned in the passage (e.g., where do lizards spend the winter; what does the sparrow
hawk eat to live), (3) a set of 2–3 why or how questions was constructed per passage, which
assessed the understanding of a basic biological principle (e.g., why is the beaver’s tale flat
and long; how do grasshoppers breathe), (4) a set of 2–4 questions dealing with some
FIG. 1. A black and white copy (the original is in color) of the Fly passage. (Reprinted, by permission of the publisher, WSOY, from Kara et al. (1989)).

detailed aspect of an illustration (e.g., name the bird in the picture; name the numbered parts of the fern in the picture) or a biological principle depicted in an illustration (e.g., how can you tell which one of two lizards is a female; arrange the pictures in the correct order and explain what series of events they depict). In Mayer’s terms (Mayer & Gallini, 1990), type 2 questions are related to nonexplanative information, type 3 questions to explanatory information, and type 4 questions to both nonexplanative and explanatory information.

Factual and comprehension questions about the text content were further divided into two categories: (a) questions about illustrated text content and (b) questions about nonillustrated text content. For questions dealing with illustrated text content, information was provided both
in the text and in an illustration. For example, the lizard’s nutrition (e.g., spiders) was mentioned in the text, and there was also a drawing depicting a lizard gazing at a spider. For the questions about nonillustrated text content, no illustration in the textbook passage was directly relevant. Across all 6 textbook passages, there were 18 questions concerning illustrated text content and 23 questions concerning nonillustrated text content.

Procedure. The subjects were tested in groups of 12–15 students. Each textbook passage was tested in a separate session each lasting 40–55 minutes. The two versions of each passage were randomly assigned between subjects with the restriction that each subject completed 3
TABLE 1
Mean Percentage Scores for the Recall of Main Points (Standard Deviations in Parentheses) as a Function of Ability Level and Passage Type (Illustrated vs Text Alone)

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Illustrated version</th>
<th>Text-alone version</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>30.5 (12.2)</td>
<td>29.0 (13.7)</td>
<td>29.7</td>
</tr>
<tr>
<td>Medium</td>
<td>24.5 (15.7)</td>
<td>22.5 (14.0)</td>
<td>23.5</td>
</tr>
<tr>
<td>Low</td>
<td>19.3 (11.5)</td>
<td>19.4 (13.5)</td>
<td>19.3</td>
</tr>
<tr>
<td>Mean</td>
<td>24.4</td>
<td>23.0</td>
<td></td>
</tr>
</tbody>
</table>

Illustrated and 3 text-alone passages. In the verbal instructions, students were asked to study carefully all information conveyed in the textbook passage. To the students studying the illustrated version, it was explicitly mentioned that the text and the illustrations make up a coherent whole, which needs to be studied. The subjects were allowed to study the passage as long as they wished, after which they were to give back the passage and were handed a question sheet. Students completed the test sheet by writing down their answers. They were given unlimited time to answer the questions.

Scoring of test materials. The answers to questions were scored blind with respect to the passage version. In scoring the list of main ideas, the student was credited one point for each main point mentioned (a maximum of 8 points per passage). Similarly, answers to detailed questions were credited one point for each correctly mentioned fact, and answers to comprehension questions were credited one point for each aspect of the questioned principle mentioned (usually 2-3 per question). No attention was paid to the exact wording of the students’ answers. Composite scores across the six passages were formed for each question type, and the scores were transformed to percentage scores.

Results

Recall of main points. Percentage scores for the recall of the main points were subjected to an analysis of variance using type of passage (illustrated vs text-alone) as a within-subject variable and level of intellectual ability (high, medium, low) as a between-subject variable.

The mean recall scores are given in Table 1. The main effect of ability reached significance, $F(2, 105) = 3.85, p < .025$; as is apparent from Table 1, recall rates increased quite linearly with ability level. Pairwise comparisons showed that the low-ability group differed significantly from the medium-ability ($p < .05$) and the high-ability ($p < .01$) groups, but the high-ability group did not differ from the medium-ability group. On the other hand, the main effect of passage type failed to reach significance, $F < 2$, and so did the Ability × Passage Type interaction, $F < 1$.

Detailed and comprehension questions. In this section, we report the overall results for detailed and comprehension questions. As noted earlier, the distinction between detailed and comprehension questions is somewhat similar to Mayer’s (Mayer & Gallini, 1990) distinction between nonexplanative and explanatory information. In the following sections, the data are further partitioned into questions about illustrated text content, questions about non-illustrated text content, and questions about illustrations.
Mean Percentage Scores for Detailed and Comprehension Questions (Standard Deviations in Parentheses) as a Function of Ability Level and Passage Type (Illustrated vs Text Alone)

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Detailed questions</th>
<th>Comprehension questions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Illustrated version</td>
<td>Text-alone version</td>
</tr>
<tr>
<td>High</td>
<td>71.3 (10.8)</td>
<td>66.8 (11.2)</td>
</tr>
<tr>
<td>Medium</td>
<td>63.9 (13.1)</td>
<td>59.7 (13.8)</td>
</tr>
<tr>
<td>Low</td>
<td>57.0 (13.1)</td>
<td>52.3 (16.0)</td>
</tr>
<tr>
<td>Mean</td>
<td>63.6</td>
<td>59.2</td>
</tr>
</tbody>
</table>

Percentage scores for correctly answering detailed and comprehension questions were subjected to an analysis of variance using the design described above. The mean scores are presented in Table 2. For the detailed questions, there was a main effect of ability, $F(2, 105) = 8.50$, $p < .001$. Pairwise comparisons (the Tukey test) showed that low-ability students differed from the other two groups ($p < .05$), and the medium-ability group marginally differed from the high-ability group ($p = .052$). Also, the main effect of passage type proved significant, $F(1, 105) = 18.01$, $p < .001$, indicating that the illustrated version produced better performance than the text-alone version. The Ability $\times$ Passage Type interaction proved clearly nonsignificant, $F < 1$. The interaction remained nonsignificant, $F < 1$, even when the analysis was repeated by including only the two extreme groups of subjects, high- and low-ability students.

For the comprehension questions, there was a main effect of ability $F(2, 105) = 9.54$, $p < .001$; pairwise comparisons (the Tukey test) showed that low-ability students differed from the other groups ($p < .05$) and that medium-ability students differed marginally from the high-ability group ($p = .06$). The illustrated version produced better scores than the text-alone version, $F(1, 105) = 7.74$, $p < .001$. The Ability $\times$ Passage Type interaction did not come out significant in the analysis of the three ability groups, $F < 2$, but did so in the analysis of the extreme groups, $F(1, 48) = 4.03$, $p = .05$. The interaction reflects the fact that high-ability students show an effect of passage type (there is a 9% difference in favor of the illustrated version), whereas, for low-ability students, the means are almost identical (see Table 2).

In sum, illustrations helped all children to answer detailed questions about them, but only high-ability children to answer the more demanding comprehension questions. To obtain illustration benefits for comprehension ques-
Table 3

Mean Percentage Scores for Questions on Illustrated Text Content (Standard Deviations in Parentheses) as a Function of Ability Level and Passage Type (Illustrated vs Text Alone)

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Illustrated version</th>
<th>Text-alone version</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>64.1 (12.6)</td>
<td>56.9 (14.2)</td>
<td>60.5</td>
</tr>
<tr>
<td>Medium</td>
<td>54.4 (17.3)</td>
<td>49.7 (17.1)</td>
<td>52.1</td>
</tr>
<tr>
<td>Low</td>
<td>44.1 (16.2)</td>
<td>42.6 (17.4)</td>
<td>43.4</td>
</tr>
<tr>
<td>Mean</td>
<td>53.7</td>
<td>49.3</td>
<td></td>
</tr>
</tbody>
</table>

Questions about text content. Percentage scores for correctly answering questions (detailed and comprehension) about the text content were subjected to an analysis of variance using the design described above. Two separate analyses were performed, one for questions about illustrated text content and another for questions about nonillustrated text content. The data for illustrated text content are presented in Table 3 and those for the nonillustrated text content in Table 4. In both analyses, the main effect of ability was highly significant, \( F(2, 105) = 6.47, p < .05 \), and \( F(2, 105) = 7.22, p = .001 \). Pairwise comparisons (the Tukey test) revealed that, in both measures, low-ability students differed from the other two groups \( (p < .05) \); for illustrated text content, the medium-ability group also differed from the high-ability group \( (p < .05) \), but not for the nonillustrated text content.

For questions about illustrated text content, the main effect of passage type also reached significance, \( F(1, 105) = 6.31, p < .02 \), suggesting a better performance for illustrated than nonillustrated passages. As is apparent from Table 3, illustrated passages produced a 4.4% improvement in performance. For questions about nonillustrated text content, the main effect of passage type was clearly nonsignificant, \( F < 1 \). In both analyses, the Passage Type \( \times \) Ability interaction failed to reach significance, both \( F's < 1 \).

Table 4

Mean Percentage Scores for Questions on Nonillustrated Text Content (Standard Deviations in Parentheses) as a Function of Ability Level and Passage Type (Illustrated vs Text Alone)

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Illustrated version</th>
<th>Text-alone version</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>71.7 (15.1)</td>
<td>74.3 (13.4)</td>
<td>73.0</td>
</tr>
<tr>
<td>Medium</td>
<td>67.5 (16.8)</td>
<td>65.9 (16.0)</td>
<td>66.7</td>
</tr>
<tr>
<td>Low</td>
<td>60.1 (15.5)</td>
<td>56.5 (16.9)</td>
<td>58.3</td>
</tr>
<tr>
<td>Mean</td>
<td>66.4</td>
<td>65.2</td>
<td></td>
</tr>
</tbody>
</table>
TABLE 5

Mean Percentage Scores for Detailed and Comprehension Questions on Illustrations (Standard Deviations in Parentheses) as a Function of Ability Level and Passage Type (Illustrated vs Text Alone)

<table>
<thead>
<tr>
<th>Ability level</th>
<th>Detailed questions</th>
<th></th>
<th>Comprehension questions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Illustrated version</td>
<td>Text-alone version</td>
<td>Mean</td>
<td>Illustrated version</td>
</tr>
<tr>
<td>High</td>
<td>73.3 (11.8)</td>
<td>56.9 (15.3)</td>
<td>65.1</td>
<td>65.5 (15.5)</td>
</tr>
<tr>
<td>Medium</td>
<td>59.8 (17.8)</td>
<td>50.8 (18.6)</td>
<td>55.3</td>
<td>57.0 (25.2)</td>
</tr>
<tr>
<td>Low</td>
<td>55.4 (15.7)</td>
<td>44.7 (16.3)</td>
<td>50.0</td>
<td>44.5 (21.4)</td>
</tr>
<tr>
<td>Mean</td>
<td>61.4</td>
<td>50.4</td>
<td>55.5</td>
<td>55.5</td>
</tr>
</tbody>
</table>

illustrated text content, but the beneficial effect did not generalize to nonillustrated text content.

Questions about illustrations. Percentage scores for questions concerning illustrations (see Table 5) were subjected to an analysis identical to that described above. A separate analysis was conducted for detailed and comprehension questions. For these questions, an illustration was reproduced and a question was asked about some aspect of its information content. It should be noted that, for most questions, relevant information was also conveyed either in text or in a figure caption, so it was also possible to answer many of them on the basis of the text-alone version.

For the detailed questions, the main effect of ability was highly significant, \( F(2, 105) = 8.47, p < .001 \). Pairwise comparisons (the Tukey test) revealed that high-ability students differed from the other groups \( (p < .01) \). Also, the main effect of passage type reached significance, \( F(1, 105) = 28.46, p < .001 \), suggesting that the presence of illustrations improved the learning of detailed illustrated content. For the comprehension questions, only the main effect of ability reached significance, \( F(2, 105) = 8.45, p < .001 \); low-ability students differed from the other groups \( (p < .05) \). There was no clear indication in the data that illustrations would have differently affected the learning performance of high- and low-ability students, both interactions proved non-significant, \( F < 2 \).

In sum, we observed that having access to an illustration increased learning of the illustrated content concerning a detail, but did not do so for learning a biological principle. Thus, students were better able, for example, to differentiate between a goshawk and a sparrow hawk when they had the opportunity to study the relevant picture. This indicates that students did pay
attention to the illustrations in our textbook materials, but intellectual ability did not seem to moderate the learning outcome.

Discussion

We obtained little support for the hypothesis that intellectually more capable children would benefit relatively more from the presence of illustrations than less capable children when learning authentic science textbook materials. This became apparent in the finding that high-ability students were aided more by illustrations in answering comprehension questions that tapped the understanding of various biological principles. Although not backed up by other similar observations, this result is in line with our prediction that the learning of authentic textbook materials is an intellectual achievement, which is handled more successfully by intellectually more capable children. We reasoned that the type of illustrated passages with several illustrations on a page, which is very characteristic of many science textbooks, requires from the student a skill of integrating pictorial and textual information in the absence of explicit cues as to how text and illustrations are conceptually related. To successfully integrate text and illustrations, the learner has to decide (1) when to look at an illustration during reading, (2) what picture to inspect, (3) what information to focus on in the illustration, and (4) how to integrate different pieces of information into a coherent mental representation. From this perspective, it is quite feasible to assume that high-ability children would be more capable of utilizing illustrations to enhance learning performance than are their low achieving peers. We admit that the prediction needs more corroborative evidence to be taken seriously.

We also observed that the learning of nonexplanative detailed information was enhanced by the presence of illustrations, but what is perhaps more interesting, high-ability students did not differ from low-ability students in the amount of obtained illustration benefits. Thus, low-ability students were capable of learning detailed information, such as naming body parts and recognizing different species, to a similar degree as their intellectually more capable peers. That high-ability students show relatively larger illustration benefits for learning basic biological principles but not detailed information is generally in line with Mayer and Gallini (1990), who demonstrated that illustration benefits primarily show up for learning of explanatory but not nonexplanatory information.

Our results are consistent with Harber (1983) who observed beneficial effects of illustrations among normally achieving children, with Reid and Beveridge (1986) who showed successful secondary school children benefit from illustrations, and with Schnottz et al. (1993) who demonstrated successful adult learners make more use of graphic information than do less successful adult learners. However, our results diverge in that we observed no detri-
mental effects of illustrations for low-ability students, as did Harber (1983) and Reid and Beveridge (1986). We argue that good intellectual capabilities are required to obtain illustration benefits, whereas Harber (1983) and Reid and Beveridge (1986) argue that the presence of illustrations distracts learning-disabled children’s attention away from the text and thus hampers successful learning. In Experiment 2, we will provide additional evidence that sheds light on this issue.

Our results also contradict those obtained by Koran and Koran (1980), who found that students with low reasoning ability were helped more by an illustration than were students with high reasoning ability. The finding was explained by the notion that low-ability learners, in contrast to high-ability students, do not spontaneously construct coherent and more elaborate mental structures of text materials, but do so in the presence of illustrations.

There is no obvious reason why our results differ from those of Koran and Koran (1980). However, our study crucially differs from that of Koran and Koran and most other previous studies in that a standard setup has been to attach a single picture to the text, while our authentic textbook passages all contained several illustrations (i.e., 3–5). As we argue above, this significantly adds to the complexity of learning materials, which in turn favors high-ability students more than low-ability students. With less complex materials, on the other hand, also less able students would be more likely to show illustration benefits. If the materials are sufficiently easy, learning performance of high-ability students may manifest a ceiling effect, whereby there is less room for illustration benefits to materialize.

Our results also seem to contradict those of Mayer and Gallini (1990), who showed a larger improvement in comprehension due to illustrations for low prior knowledge than high prior knowledge adult subjects. However, the contradiction may be more superficial than real for at least two reasons. First, prior knowledge is conceptually quite distinct from intellectual ability. Second, even assuming that the two concepts correlate empirically, the studies differ in Mayer and Gallini’s recruiting clearly older college students for their study while our subjects are on the first ladder steps of becoming proficient learners. In terms of mature learning strategies, our most skilled children may begin to approach the level of the least able college students. Consequently, the two studies hint at the possibility that they are these intermediate-level learners (i.e., high-ability elementary school students and low-ability college undergraduates) who would benefit the most from illustrations. Due to their immature intellectual capabilities, the least able young children would be unable to make use of illustrations, whereas skilled adult learners at the other end of the continuum would not need the help of illustrations to derive an elaborate mental representation. Naturally, developmental studies will be needed to test these assumptions.
The finding that learning illustrated text content is facilitated by illustrations, while learning nonillustrated text content is not, compares favorably with the conclusions put forth by Levie and Lentz (1982). This result suggests that, in order for the illustration to have a beneficial effect on learning, the illustration has to be pertinent and directly relevant to the text content. In other words, illustrations do not seem to be able to bring about a general facilitatory effect that would enhance learning of all aspects of the text content.

Levie and Lentz (1982) estimated the effect size of illustrations by subtracting the grand mean of the text-alone condition from the grand mean of the illustrated condition and then dividing by the standard deviation of the text-alone condition. Using this algorithm, we calculated our effect size to be 0.26, which is lower than what has been observed in most previous studies reviewed by Levie and Lentz (1982). As pointed out above, unlike most previous studies, we used authentic textbook materials, which were tested in a natural classroom situation. Thus, our small effect size may be seen as somewhat discouraging with respect to learning benefits of illustrations that can be obtained in real-life learning environments.

EXPERIMENT 2

To more fully understand the effects of illustrations on learning textbook materials, it is important to know how illustrations guide learners’ attention during studying: To what extent do illustrations attract learners’ attention? Is the timing of inspecting illustrations optimal for learning? Do children pay attention to relevant features of illustrations? How much do children go back and forth between text and illustrations? As our knowledge about these questions is restricted, we designed an experiment, which will provide direct evidence on attention guidance during studying of illustrated textbook passages.

Attention guidance was examined by measuring children’s eye movements when they studied six illustrated textbook passages. Eye movement recordings yield an on-line record of where learners gaze from moment to moment and for how long they fixate on different segments of a textbook passage, such as text or illustrations. It has been convincingly shown that there is a close relationship between where the eyes gaze and where the attention is engaged during processing of visually presented information (see, e.g., Rayner, 1992), so the measurement of eye fixation patterns is an optimal method for studying attention guidance during textbook learning.

We were particularly interested in seeing whether the on-line learning process would differ as a function of intellectual ability. For experiment 2, 12 high-ability and 12 low-ability students were selected from the same sample.
used in Experiment 1. The students were from the two ends of the ability continuum: the highest and lowest achieving children of the 4th grade class.

Two alternative predictions can be made. On the basis of the results of Experiment 1, high-ability children are expected to show a greater amount of integrative processing for text and illustrations; in other words, they are expected to frequently gaze back and forth between text and illustrations. On the other hand, on the basis of the study by Reid and Beveridge (1990) and Hegarty et al. (1991), low-ability children are expected to pay relatively more attention to text illustrations than are high-ability children.

**Methods**

**Subjects.** Twenty-four subjects were selected from the same sample used in Experiment 1: a group of 12 students (7 girls, 5 boys) who obtained top scores in the Raven test and another group of 12 students (6 girls, 6 boys) whose Raven test scores were among the lowest. The composite score of the C, D, and E sets ranged between 21–33 for the high-ability group and between 0–20 for the low-ability group. The averages were 24.7 (SD = 2.4) and 11.8 (SD = 5.7) for the high and low ability groups, respectively. To make comparisons to test norms, we first transformed the average test scores of the two groups based on the C, D, and E versions to expected total scores with the help of the test manual (Raven et al., 1992). In comparison to the British norms (Raven et al., 1992), the high-ability group scored, on average, at the 90th percentile and the low-ability group at the 10th percentile.

**Apparatus.** Eye movements were recorded using an Applied Science Laboratories Model 1994 eye-tracker. This monitoring system is video-based and makes use of pupil and corneal reflections. Its accuracy has been estimated as 0.65° horizontally and 0.35° vertically by using a 16° × 16° stimulus array (Muller, Cavegn, d’Ydewalle, & Groner, 1993). A chin rest and a head restraint were used to restrict possible head movements. In addition, a head-movement compensation system is built into the monitoring system. Pupil and corneal reflections of the left eye were recorded with a special video camera placed approximately 70 cm away from the subject. Another standard video camera placed behind the subject viewed the textbook passage positioned in a wooden frame, which stood on an adjustable table. With the help of these two cameras, the eye monitoring system provided a video recording, where a dot showing the gaze position and moving along with the left eye was superimposed on the video picture of the viewed visual area. All eye movement data reported are based on analyses of these video recordings, which were conducted manually by the first author.

**Materials.** Six textbook passages were selected from two 4th-year elementary school biology books, *Värikäs luonto 4* (Kara, Koskenniemi, Kovakoski, & Nurmi, 1989) and *Koulun biologia 4* (Mattila, Nyberg, & Vestelin, 1991), each about a distinct topic (frogs, beaver, bat, chaffinch, flies, and alder). None of the passages was used in Experiment 1. In all passages, the illustrations were linked to the text content, although to a variable degree, some being more relevant to the text than others. There were 3–6 illustrations per passage, both color and black-and-white drawings and photographs were used. In the text, no explicit reference was made to illustrations. An example of the type of textbook passage used is presented in Fig. 1. The passages were clipped from the original textbooks and glued onto a piece of cardboard, which was then placed on a wooden frame for presentation.

A question sheet was prepared for each passage that was similar in structure to the ones used in Experiment 1. Thus, subjects were first asked to name the main points, after which factual and comprehension questions were asked about the text content as well as about the
TABLE 6
Mean Percentage Scores for the Recall of Main Points, Comprehension and Detailed Questions (Standard Deviations in Parentheses), and Average Fixation Time (in Seconds) on Different Segments of Textbook Passages for the High- and Low-Ability Children

<table>
<thead>
<tr>
<th></th>
<th>High-ability children</th>
<th>Low-ability children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall of main points</td>
<td>32.5 (16.9)</td>
<td>11.5 (10.3)</td>
</tr>
<tr>
<td>Comprehension questions</td>
<td>68.5 (15.6)</td>
<td>26.6 (15.5)</td>
</tr>
<tr>
<td>Detailed questions</td>
<td>73.5 (12.7)</td>
<td>44.0 (12.4)</td>
</tr>
<tr>
<td>Fixation time on text</td>
<td>270.8 (111.5)</td>
<td>221.6 (97.8)</td>
</tr>
<tr>
<td>Fixation time on illustrations</td>
<td>20.3 (14.2)</td>
<td>16.6 (13.6)</td>
</tr>
<tr>
<td>Fixation time on figure caption</td>
<td>40.5 (15.9)</td>
<td>32.7 (15.7)</td>
</tr>
<tr>
<td>Fixation time on blank space</td>
<td>0.7 (0.3)</td>
<td>1.4 (0.6)</td>
</tr>
</tbody>
</table>

content of illustrations. For the last two passages tested, subjects were also asked for a free recall of everything they could remember about the illustrations.

Procedure. Subjects were instructed to study the content of the passage carefully in order to be able to answer questions about it. It was explicitly mentioned that each passage consisted of both text and illustrations and that they were required to study all information presented in the passage. Subjects were given unlimited time for studying. The question sheet was handed to them immediately after completing studying each passage. Each textbook passage was presented in a separate session lasting 30–40 minutes. Prior to the study phase, the eye-tracker was calibrated using a 9-point calibration grid. To minimize head movements, subjects were asked to keep their heads still in the chin rest.

Scoring. The answers to questions were scored using the same procedure as those in Experiment 1. The analysis of eye movements was done from video recordings. All analyzed eye-movement measures are based on the time spent fixating on different segments of a textbook passage: time spent on text, illustrations, figure captions, and blank spaces. Fixation times were measured from the video tapes with a stopwatch. In some analyses, absolute fixation times were used as dependent measures; in other analyses, fixation times were used to obtain scaled measures to assess processing strategies. For example, the extent of gazing back and forth between a text segment and a related illustration was assessed using a 5-point rating scale (see Results for further details).

Results

In the following, we first report results for the comprehension and recall tests, followed by analyses of eye fixation patterns; the primary focus is on the eye fixation data.

Comprehension and recall tests. Separate analyses of variance were performed on the recall of main points, comprehension questions (about basic biological principles), and detailed questions using intellectual ability as the between-subject variable (low vs high ability). Percentage scores for the three types of questions are presented in Table 6.

Recall of main points was better for high-ability than low-ability students, $F(1, 22) = 13.41, p < .01$. Similarly, high-ability students outperformed low-ability students in answering more successfully both comprehension, $F(1, 22) = 42.85, p < .001$, and detailed questions, $F(1, 22) = 35.71, p <$
When question type was used as a within-subject variable, there was a significant Question Type × Ability interaction, $F(2, 44) = 13.78, p < .001$, suggesting that there was a more pronounced difference between high-ability and low-ability children in answering comprehension than detailed questions.

In sum, these analyses confirm that the two student groups clearly differed in the ability to comprehend and recall textbook materials. Moreover, the finding that the difference between ability groups was more pronounced for explanatory (comprehension questions) than nonexplanatory (detailed questions) information is in line with the results of Experiment 1.

**Analyses of eye fixation patterns.** Analyses of variance were performed on the eye movement data using intellectual ability as a between-subjects variable. Average fixation times on different segments of textbook passages are given in Table 6 for the two ability groups. The total time spent on reading the text did not differ significantly between the groups, $F < 2$. High-ability children tend to read the texts for a longer time but, due to large variances, the difference did not come out statistically significant. Second, the reading speed was calculated by computing the total time spent reading the text once through (not including figure captions) divided by the number of words. High-ability students read with a faster speed (105 words/minute) than low-ability (77 words/minute) students, $F(1, 22) = 4.73, p < .05$. Taken together, these two findings suggest that high-ability students spent more time rereading parts of the text.

Time spent on looking at illustrations did not differ between the groups, $F < 1$, neither did the fixation frequency on illustrations, $F < 1$. Even a separate analysis for the most visualized passages (bat and fly) did not reveal a difference between the groups in the amount of time spent on inspecting illustrations, $F < 1$. Neither did the groups differ in the time spent on reading the figure captions, $F < 2$. However, low-ability students spent more time gazing at irrelevant blank spaces between and around text and illustrations, $F(1, 22) = 11.06, p < .01$. This finding can be seen as a reflection of low-ability children getting occasionally distracted from the learning task. Further evidence for the distraction interpretation comes from the Bat passage, the other of the two most visualized passages, which has a large, mean-looking flying bat presented at the beginning of the passage. The Bat passage was accompanied by more time spent on irrelevant blank spaces than others (1.4 versus 0.9 s). In pairwise comparisons, the Bat passage differed significantly from all other passages (all $p$’s < .05), while the other passages did not.

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1 By definition, a visualized passage is one including large illustrations and where the text begins after an illustration (for an example, see Fig. 1). For the two most visualized passages (bat and fly), the area covered by illustrations was twice as large as the area covered by text (42% vs 21%).
differ from each other. For the Bat passage, low-ability children produced marginally more fixation time on blank spaces than did high-ability students, \( F(1, 22) = 3.65, p = .07 \).

Although the overall gaze times for text and illustrations did not differ between the two groups, differences were observed in how children allocated their total processing time. This became apparent in follow-up analyses, which examined in more detail the on-line learning process. In the first analysis, we categorized illustrations as pertinent and less pertinent ones by choosing the most pertinent and the least pertinent illustration of each passage. For example, in the Fly passage (see Fig. 1), the pertinent illustration was one depicting the metamorphosis of a fly from an egg to an adult, and a photograph of a mosquito was defined as the least pertinent. Using fixation times as the dependent measure, we observed that children devoted significantly more visual attention to pertinent than less pertinent illustrations, \( F(1, 22) = 29.05, p < .001 \); the average viewing times were 7.1 and 2.0 s for pertinent and less pertinent illustrations, respectively. On the other hand, the two ability groups did not differ from each other in the amount of time they spent on inspecting pertinent and less pertinent illustrations, \( F < 2 \).

For the second analysis, pertinent information was distinguished from less pertinent information separately for each text and illustration. For example, in the passage about bats, the text paragraph describing how a bat navigates was defined as a pertinent text segment; in the color picture illustrating a bat navigating, a pertinent segment was one showing a bat in action, and less pertinent segments were the house and the moon shown in the background. The amount of time spent on pertinent segments of text and illustrations was then assessed using a 5-point scale, where 5 denoted marked slowing down of reading speed for and frequent reinspection of pertinent segments and 1 denoted very minimal processing of pertinent segments. For example, the subject received a score of 5 when s/he spent at least 80% of the time on illustration in inspecting the pertinent aspects of the illustration, a score of 3 when s/he divides the study time roughly equally between pertinent and less pertinent segments of the illustration, and a score of 1 when s/he spends more than 80% of the time on irrelevant features of the illustration. The average interitem correlation across the six passages was .87 for the text and .67 for the illustrations.

The groups differed in the amount of visual attention they paid to pertinent text segments, \( F(1, 22) = 47.23, p < .001 \), as well as to pertinent segments in illustrations, \( F(1, 22) = 30.50, p < .001 \). High-ability students paid much more attention to pertinent segments than did low-ability students. The average ratings for pertinent text segments were 3.68 and 1.58 and those for pertinent segments of illustrations 3.99 and 2.53, for the high- and low-ability students, respectively.
In the next analysis, we examined the interplay between text and illustration by selecting segments from the passages for which there was a tight meaning-related link between a text segment and an illustration. For example, in the passage about flies (see Fig. 1), the metamorphosis of a fly was described both in a text paragraph and in an illustration. The amount of time children looked back and forth between the relevant illustration and the target text segment was again assessed using a 5-point scale, where 5 denoted extensive back-and-forth looking and 1 no such interaction between text and illustration. To obtain a score of 5, the subject had to make at least 3 relatively long fixations on the relevant illustration from the corresponding text segment; for a score of 3, s/he made only one or two short fixations from the relevant text segment to the corresponding illustration; to obtain a score of 1, s/he did not make any such fixations. The average interitem correlation across the six passages was .62.

We found that high-ability students did more back-and-forth looking than did low-ability students, $F(1, 22) = 24.54, p < .001$; the average ratings were 2.6 and 2.0, respectively. Moreover, the interplay between text and illustration was greater for the most visualized passage (i.e., fly; see the footnote) than for the other passages, $F(1, 22) = 19.18, p < .001$. What may also be noted is that, overall, the scores were pretty low, suggesting that there was little back-and-forth looking between a relevant text segment and a corresponding illustration.

Finally, we computed correlations between the time spent on studying the text and illustrations and the success in answering questions about them. The correlation between the success in answering detailed and comprehension questions about illustrations and the time spent on inspecting the illustrations was positive (.14), but clearly nonsignificant. There was also a nonsignificant positive correlation (.27) between memory for illustrations and time spent on text. As a next step, we computed a separate correlation between time spent on text and memory for illustrations for the last two passages, for which children were explicitly asked to recall everything they could remember about the illustrations. The correlation was .58 for the Fly passage and .31 for the Alder passage; the former correlation was significant, but the latter was not. Moreover, there was a significant .49 correlation between time spent on text and recall of main points of the passage. Time spent on text also correlated positively with the success of answering detailed (.35) and comprehension (.30) questions, although the correlations did not quite reach significance.

**Discussion**

Experiment 2 found no differences between low- and high-ability children in the amount of time spent in inspecting textbook illustrations. Both groups
spent surprisingly little time in studying the illustrations; only 6% of the total study time was spent on inspecting illustrations. This strongly suggests that learning was heavily text-based. Children even devoted twice as much study time to figure captions as to the illustrations themselves. That the memory for illustrations correlated more strongly with time spent on text than time spent on illustrations also supports the notion that the learning process was strongly governed by the text. These observations are completely parallel to those made by Hegarty et al. (1991) for adult subjects. They also observed that the processing of illustrated text content is largely driven by the text.

The ability groups differed in two interesting ways. First, high-ability students spent more time on rereading the text than did low-ability students. Second, high-ability students devoted relatively more time to studying pertinent segments of text and illustrations than did low-ability students, and they carried out more back-and-forth looking between text and a relevant illustration. We suggest that these findings reflect high-ability students’ more mature learning strategies: concentration on pertinent information and on integrative processing.

As we have argued above, to extract information from biology textbook passages is an achievement that requires good intellectual capabilities. For example, an illustration series depicting the metamorphosis of a fly or a frog from an egg to an adult individual cannot be grasped at a single glance, but requires careful inspection. In our data, this was reflected in relatively long viewing times for such pertinent illustrations. Moreover, to fully comprehend the illustrated message, the learner also needs to consult the relevant sections of the text content for additional information. All in all, utilization of illustrations during studying science textbook materials often calls for good intellectual skills and mature learning strategies, which are characteristic of high-ability students.

GENERAL DISCUSSION

The results of Experiments 1 and 2 appear to converge on the point that the high-ability children tend to obtain somewhat larger illustrations benefits in learning outcomes and to spend relatively more time studying pertinent rather than less pertinent information and on looking back and forth between a text segment and the corresponding illustration. These observations suggest that the larger illustrations benefits may be due to more attention’s being devoted to pertinent aspects of text and illustrations and to more effort’s being made to integrate text and illustrations. That the study time (particularly for text), in general, is related to the learning outcome is further supported by positive correlations between study time and the success in answering questions about the materials afterwards.
The attentional hypothesis outlined above is consistent with the selective attention strategy proposed by Reynolds (1992) for text comprehension. According to this notion, learning outcome is significantly mediated by the type of processing done during learning. For example, by spending more time in processing relevant text segments, the relevant information is well represented in memory and becomes thus more readily retrievable later. Of the evidence supporting this notion, we mention two studies. Reynolds, Shepard, Lapan, Kreek, and Goetz (1990) demonstrated that 10th grade students devoted more time to reading text segments containing information relevant to inserted questions. Similarly, Hyöna, Kaakinen, and Keenan (1997) showed that adult readers spent more time on reading text segments that were relevant to the given reading perspectives than on perspective-irrelevant segments. At the same time, they recalled more perspective relevant than irrelevant information. The described relationship between processing time and recall rate should certainly not be considered a pattern that would generalize to a range of reading situations and texts. For example, Vauras, Hyöna, and Niemi (1992) showed that an incoherent text structure produced longer reading times but poorer recall than did a coherent text structure. Moreover, the data of Hyöna et al. (1997) suggest that the attentional hypothesis would hold for a text topic about which the readers have minimal prior knowledge, but not for contents about which they possess a wealth of prior knowledge.

There was some suggestion in our data that illustrations may, in fact, be harmful for poorer learners. They were found to spend more time away from the task of studying text and illustrations, particularly in the case of the most visualized passage. This observation is in line with the notion proposed by Harber (1983) that pictures distract low-ability learners’ attention away from the actual learning task and that pictures may, in fact, be a hindrance to learning. However, as the distraction effect contributes only minimally to the total time spent on task, we conclude that it is not, by any means, a major determinant of low-ability children’s poor learning performance. Also, it may be noted that the gazing at the blank area in the page may not necessarily reflect distraction from the task; it may also be a sign of fatigue or a way of avoiding studying. The problem with this interpretation is that it is not clear why the fatigue particularly coincides with the most visualized passage.

It is plausible to argue that general intellectual ability is confounded with reading ability and that observed differences between high- and low-ability children would instead be accounted for by differences in their reading ability. The ability to read consists of two major cognitive operations: the ability to decode words and the ability to comprehend ideas conveyed in text. Undoubtedly, general intellectual ability correlates with the ability to compre-
hend written texts so that it would be very difficult to ‘‘unconfound’’ these two factors. On the other hand, it may be noted that Hyöna (1994) showed with a similar sample of 5th graders attending the same school as the students of the present study that even poor comprehenders make clear attempts to integrate subsequent text segments together while reading expository texts. Thus, it seems not very likely that our low-ability group would not have made any effort to integrate text and illustrations.

With respect to decoding ability, it is possible to argue that the children comprising our low-ability group would have an insufficient decoding ability to be able to extract information from text to allow its successful integration with the illustrations. Although we cannot completely rule out this possibility, we think we are in a position to render this interpretation unlikely. The evidence comes from average reading speeds that may be used as estimates of decoding ability (i.e., poor decoding results in a slow reading speed). The low-ability children read the passages with an average reading speed of 77 words per minute (wpm), which figure is very similar to the one obtained by Hyöna (1994) for poor 5th grade comprehenders (81 wpm). As pointed out above, despite their slow reading, these 5th grade readers showed clear signs for integrative processing. By way of analogy, we argue also that our low-ability children possess sufficient decoding ability to render reading for comprehension possible. This argument is further supported by the fact that the boys of the high-ability group read with a speed similar (72 wpm) to that of the low-ability group (the girls of the high-ability group read with clearly faster speed, i.e., 129 wpm). Finally, it may be noteworthy that previous research has assumed the relationship between reading ability and the utilization of illustrations to be in the opposite direction than assumed above: poor decoders are expected to make more use of illustrations than are good decoders (Levie & Lentz, 1982; Willows et al., 1981). As poor decoders lack fluency in the basic reading processes, they are assumed to rely more on and pay more attention to pictorial information (Willows et al., 1981). However, the supportive evidence is meager and inconclusive (see Harber, 1980; Levie & Lentz, 1982; Rusted & Coltheart, 1979).

A potentially useful direction for future research is to study the utilization of illustrations in a condition where the text contains explicit references to relevant pictures. As may be recalled, in our textbook passages, no reference was made in the text to any illustration. As the text appears to be the driving force in learning of textbook passages, explicit cues to how text and illustrations are related in content should increase the illustrations benefits. This is for at least two reasons: first, because this kind of signaling should increase the time spent on inspecting illustrations, and second, because such signals should make attempts at integrating relevant text and illustration contents more likely. It would also be interesting to examine whether signaling benefits would be greater for low-ability than for high-ability students.
A second potentially useful direction for future research is to examine the development of the utilization of illustrations during textbook learning. As we pointed out above, there may be good reasons to expect the relative illustration benefits to increase significantly as a function of the emerging of more mature learning skills.

The results of the present study have implications for classroom practice. First, as children appear to inspect illustrations only minimally, teachers should encourage students to pay attention to textbook illustrations. Teachers should also point out that similar information is conveyed in both text and illustrations and that comprehension is improved when a text segment and its accompanying illustration are studied together. Finally, the ability to extract pertinent information from illustrations can be improved by the teacher’s analyzing, together with the students, the information content of often complex science textbook illustrations.

REFERENCES


