Comparison of Two Cognitive Strategies for Learning from Illustrated Texts

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Abstract: Learning from illustrated text is often expected to be more beneficial than learning from text alone. Nevertheless, learners often fail to adequately process text-picture-combinations. One option to support learners and foster learning would be to provide them with strategies for learning from text-picture-combinations. Up until now, however, such comprehensive strategies have not been available. We have therefore conceptualized two strategies, based on current models of multimedia learning, for learning from text-picture-combinations. Both strategies aim to enhance the same cognitive processes by encouraging either internal, or internal and external learning activities. An experimental study was conducted to investigate whether sixth-grade students with varying cognitive abilities (high vs. low ability) apply the two strategies differently. Within both levels of ability, learning with the strategy that encourages internal and external learning activities led to superior learning gains. An analysis of think aloud data revealed differences in the quality of the students' strategy use.

1 INTRODUCTION

Learning with the computer is typically equated with multimedia learning, which Mayer (2005) defined as: "presenting both words (such as spoken text and printed text) and pictures (such as illustrations, photos, animation, or video)" (p.2). On the basis of this definition, text-picture-combinations can be understood as a fundamental form of multimedia learning. Therefore, research on text and picture can also be revealing for learning with the computer in general.

It is believed that adding pictures to a text fosters learning. Furthermore, research shows that students learn more from an illustrated text than from text alone (e.g. Mayer, 2001). Learners, however, do not automatically process texts and pictures appropriately. They often have difficulty encoding complex pictures or combining information provided in the text and the picture (e.g. Ainsworth et al., 2002; Levie and Lentz, 1982). How can learners therefore be supported to successfully process text-picture-combinations?

One approach to support learning is to improve the design of the learning material. Over the past 15 years, various principles for improving the design of text-picture-combinations have been proposed and empirically evaluated (e.g. Mayer, 2005). Research has demonstrated, however, that the principled design of learning material alone does not guarantee successful learning; even well designed material does not necessarily lead to an active processing of the representations (e.g. Bartholomé and Bromme, 2006; Dean and Kulhavy, 1981). An active processing of the text and picture information is essential to understanding the learning material (Wittrock, 1990). Moreover, learners are often confronted in daily life with materials that are not "well" designed (cf. Mayer, 1993).

Research on text understanding has shown that learning strategies which take a more learner-orientated approach can effectively support learning (e.g. Dansereau et al., 1979; Mandl and Friedrich, 2006). According to our knowledge, there are currently no comprehensive strategies available for learning from text-picture-combinations, and only a few isolated techniques for learning from pictures (e.g. Peeck, 1994; Seufert, 2003) have been proposed up until now. Based upon previous strategic learning research and current models of multimedia learning, we have developed two learning strategies which aim to systematically foster learning from illustrated

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texts. While one strategy encourages internal learning activities, the other strategy encourages internal and external learning activities. An experimental study was conducted to analyze whether learners with varying cognitive abilities apply the two strategies differently.

2 PREVIOUS RESEARCH ON STRATEGIC LEARNING WITH TEXT AND PICTURES

According to Streblow and Schiefele (2006), a learning strategy is defined as "... a sequence of efficient learning techniques, which are used in a goal-orientated and flexible way, are increasingly automatically processed, but remain consciously applied" (p. 353; translation by the authors). Thus, learning techniques, such as underlining important statements in a text or annotating a text or picture, are individual components of a strategy. Several learning techniques combined together in a goal-orientated way form a learning strategy.

Early research on learning strategies was mainly oriented towards text. Models which describe relevant processes for text understanding were formulated on a theoretical level (e.g. Kintsch and van Dijk, 1978). On an empirical level, Marton and Säljö (1984) identified two approaches to learning. They differentiated between a surface level approach and a deep level approach. In the surface level approach, learning focuses mainly on the repetition of information in order to remember it. In the deep level approach, elaborative activities lead to an understanding of the information. It has been repeatedly demonstrated that text comprehension is improved when learners utilize the deep level approach (see also Dornisch et al. 2011; Schlag et al., 2007). On the basis of these theoretical models and empirical findings, different strategies which aim at fostering relevant deep level processes have been developed and evaluated. Examples are the PQ4R-Method (Preview, Question, Read, Reflect, Recite, Review, Thomas and Robinson, 1972) and the MURDER strategy (Mood, Understanding, Recall, Digest, Expanding, Review, Dansereau et al., 1979; for an overview see Mandl and Friedrich, 2006).

Current learning materials, however, consist not only of text but include large numbers of illustrations as well. Mayer (1993) has already shown that half of the space in an average science textbook is reserved for pictures. This development was taken into account at the theoretical level by conceptualizing processing models for learning with illustrated texts (e.g. Mayer, 2001; Schnotz and Bannert, 2003). These models describe processes which are considered to be essential for learning from illustrated texts. Up until now, however, only a few approaches which foster strategic learning from text-picture-combinations have been proposed. In addition, a few isolated techniques have been developed with respect to facilitating learning from pictures, e.g. learners were requested to pay attention to a picture (Peeck, 1994) and to answer questions concerning a picture (Peeck, 1994; Weidenmann, 1994).

3 CONCEPTUALIZATION AND EVALUATION OF A LEARNING STRATEGY

When developing strategies for learning from text-picture-combinations, it is necessary to first identify the processes relevant for learning. Various processing models for learning from text-picture combinations consider similar processes to be important for learning (Mayer, 2001; Schnotz and Bannert, 2003). For instance, in his model of multimedia learning, Mayer (2001) emphasizes three kinds of cognitive processes: *selection*, *organization,* and *integration of information*. Furthermore, the model assumes *transformation processes*.

Selection processes aim at selecting relevant internal and external information. When learning with text-picture-combinations, special attention should be given so that the relevant information from both sources is selected. *Organisation processes* take place when the selected information is correlated to each other. *Integration processes* integrate information from the text and pictures, as well as prior knowledge, into one coherent mental model. *Transformation processes* occur when verbal representations are transformed into pictorial representations and vice versa. Since each of these processes might take advantage of prior knowledge, we do not consider elaborations to be a separate process category. Rather, we assume that each of these processes can fulfill elaborative functions.

Already existing models of multimedia learning served as the foundation for developing a strategy for learning from text-picture-combinations. For each process mentioned above, learning techniques that aim to induce the relevant processes were formulated. While some techniques could be taken directly from literature on learning from texts and learning from pictures, other techniques had to be

constructed by drawing an analogy to already existing techniques. For example, a common technique which supports text comprehension is to identify and underline relevant phrases. A possible analogous technique to support picture comprehension could be to identify and mark relevant entities within the picture. The formulated techniques promote internal as well as external learning activities (cf. Table 1); the external learning activities (e.g. underlining) thereby facilitate internal learning activities (e.g. selection of phrases).

Table 1: Strategy to encourage internal and external learning activities.

Cognitive processes	Learning technique
Selection and organization	a) *Get an overview:* Shortly read the text and look at the picture in order to get an overview. b) *Identify relevant aspects in the text and picture*: Underline the phrases in the text that are important to you. Search for entities in the picture that correspond to the phrases and mark them. Now label the marked entities with the underlined phrases.
Integration and transformation	c) *Establish relations between the text and picture:* Write a summary of what is represented on the whole in the text and picture. d) *Visualize important information*: Draw a sketch that illustrates which information from the text and picture is most important to you.

An experimental study was conducted to evaluate the effectiveness of the strategy (Schlag and Ploetzner, 2011). Overall, 133 sixth-grade students from two different middle schools participated in the study. Both groups learned from various text-picture-combinations about honeybee dances. While one group had to write a summary of what they learned, the other group took advantage of the learning strategy. Both groups worked on a pre- and a post-test. The *strategy group* (M = 13.24, SD = 3.72) outperformed the *summary group* (M = 9.75, SD = 3.68). The groups differed significantly in the overall post-test results ($F(1,130) = 24.55$, $p < .01$, $\eta^2_p = .16$), as well as on the sub-tests with respect to factual, conceptual, and transfer knowledge.

We also analyzed the worksheets from the strategy group and evaluated the quality of the markings, labels, underlines, summaries and visualizations that were produced by the students. We expected to see a positive relation between the quality of the worksheets and the post-test results: students who produced high-quality worksheets were expected to gain higher scores on the post-test. However, there was no significant correlation between the quality of the worksheets and the post-test results ($r = .297$, n.s.).

The study demonstrates that students who utilized the strategy learned better than the students who applied the common learning technique of writing a summary, which is often taught and used in school. In contrast to our expectations, however, no significant correlation was found between the quality of the worksheets and the post-test results. This finding indicates that the cognitive processes and externalizations produced during learning are not the same. While some students with high post-test results performed poorly on the worksheets, other students did well on the worksheets but nevertheless obtained poor results on the post-test. Thus, the students seem to apply different cognitive processes with varying quality when taking advantage of the learning strategy.

A learner's cognitive ability is an important predictor of how they process information (e.g. Kozma and Russel, 1997). Learners with high cognitive abilities might be able to deeply process the information after being given general suggestions on how to approach the learning material. These learners might not need support to produce specific external representations in order to understand the material; it could even be that such specific guidance hinders learning (cf. the effects of scaffolding and fading; e.g. Kirkley, 2006; Quintana et al., 2006). In contrast, learners with lower cognitive abilities might not profit from general suggestions. They might require more specific guidance on how to process the material.

A second strategy focusing on internal activities rather than encouraging external activities was therefore formulated. Both strategies aim at inducing the same cognitive processes by either encouraging internal and external or only internal learning activities (see Table 2).

The *strategy that encourages internal learning activities* supports students "thinking" (e.g. selection of phrases). The *strategy that encourages internal and external learning activities* supports the same cognitive processes through external activities (e.g. underlining). The external activities should facilitate the internal information processing. Peeck (1993) assumes that instructional interventions which result

in "an external and controllable product" (p.234) should be most successful.

Table 2: Two learning strategies.

cognitive processes	Learning techniques that encourage internal and external activities	Learning techniques that encourage internal activities
Selection and organization	a) *Get an overview:* Shortly read the text and look at the picture in order to get an overview.	a) *Get an overview:* Shortly read the text and look at the picture in order to get an overview.
	b) *Identify relevant aspects in the text and picture*: Underline the phrases in the text that are important to you. Search for entities in the picture that correspond to the phrases and mark them. Now label the marked entities with the underlined phrases.	b) *Identify relevant aspects in the text and picture*: Clarify the phrases in the text that are important to you. Search for entities in the picture that correspond to the phrases.
Integration and Transformation	c) *Establish relations between the text and picture:* Write a summary of what is represented on the whole in the text and picture.	c) *Establish relations between the text and picture:* What is represented on the whole in the text and picture?
	d) *Visualize important information*: Draw a sketch that illustrates which information from the text and picture is most important to you.	d) *Visualize important information*: Imagine the information from the text and picture that is most important to you.

4 STUDY

4.1 Research Question and Hypothesis

Do students with varying cognitive abilities profit differently from the two learning strategies described in Table 2? We hypothesized that students with low cognitive abilities would profit more from the strategy that encourages internal and external learning activities, whereas students with high cognitive abilities would profit more from the strategy that encourages internal learning activities.

Different forms of support might be advantageous to students with varying cognitive abilities. Students with low cognitive abilities, for example, could benefit more from the strategy with specific guidance. Such a strategy helps to orientate students by specifically instructing which activities are supposed to be carried out. In contrast, a strategy with less guidance might be more beneficial to students with high cognitive abilities. These students should be capable of independently generating the appropriate learning activities by themselves.

4.2 Method

4.2.1 Design

Two factors were varied in a 2x2-design: a) *learning strategy* (strategy that encourages internal and external learning activities vs. strategy that encourages internal learning activities) and b) *cognitive ability* (high vs. low cognitive ability).

4.2.2 Participants

Overall, 24 sixth-graders (12 girls and 12 boys; mean age: 11.79, SD = .66) from three schools in South-West-Germany participated in the study. There were 4 groups, each with six students. Both sexes were evenly distributed across the groups. The students were from three different types of German secondary schools (Gymnasium, Gesamtschule, and Realschule). Participation was voluntary and participants received financial compensation.

4.3 Material

4.3.1 Learning Material

The learning material dealt with the dances of the honeybee. The students had to learn about the round dance and the waggle dance and how bees use the dances to communicate the distance of food sources (see Figure 1). The material was composed of four text-picture-combinations. The relevant information was placed in both the text and the picture so that students had to take both representations into account in order to understand the bee dances.

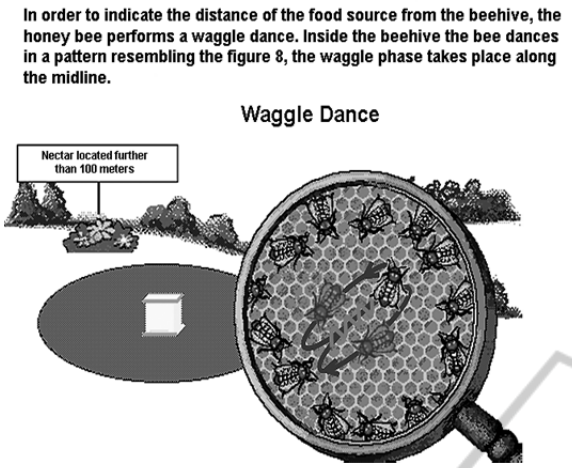

Figure 1: Example of the learning material (picture taken from Microsoft Encarta 2002; screenshot reprinted with friendly permission from the Microsoft Corporation).

4.3.2 Learning Strategies

The students in both groups were respectively given worksheets which detailed either the *strategy that encourages internal and external learning activities* or the *strategy that encourages internal learning activities* (see Table 2). The students were requested to make use of the worksheets during learning.

4.3.3 Pre- and Post-Test

In order to assess prior knowledge, participants were given a pre-test consisting of eight items. The post-test consisted of 24 items: eight on factual knowledge, which were the same as on the pre-test, eight on conceptual knowledge, and eight on transfer knowledge.

4.3.4 Assessment of Cognitive Abilities

Cognitive ability was assessed with the Mannheim Intelligence Test *MIT-KJ (*Mannheimer Intelligenz-test für Kinder und Jugendliche; Conrad, Eberle, Hornke, Kierdorf and Nagel, 1976). The test measures general intelligence of children between nine and fifteen years old by assessing three verbal, one mathematical, and two visuospatial abilities. The intelligence scale ranged from one to ten points. Students scoring five points or less on the scale were assigned to the low cognitive ability group, whereas students scoring six points or more were assigned to the high cognitive ability group.

5 PROCEDURE

All students were individually assessed. They were initially tested by means of the MIT-KJ (Conrad et al., 1976) in order to assign them to the low or high cognitive ability group. The students were then randomly assigned to one of the *strategy groups*. Thereafter, all participants completed the pre-test. In order to familiarize them with the think aloud method, they took part in a training which included a practice task of 15 minutes. The students in both strategy groups received a short introduction on how to take advantage of their learning strategy. During the learning period, the students worked independently and utilized the worksheets to learn from the four text-picture-combinations about the dances of the honeybee. For each text-picture-combination, the students were given a new work-sheet. The students were requested to continuously think aloud during the learning period. Their verbalizations were recorded. The learning time was limited to 50 minutes. The students were free to finish earlier. The post-test took place after the learning phase.

6 RESULTS

6.1 Analysis of Pre- and Post-Test Results

The students answered on average 1.38 (SD = .78) of eight questions correctly on the pre-test. All four groups performed nearly the same on the pre-test (M between 1.50 and 1.33). There were no significant differences between groups on the pre-test ($F(3,20) = .06$, n.s.).

The learning time was on average 27.08 minutes (SD = 13.87). Students using the strategy that encourages internal and external activities learned on average longer (M = 36.71, SD = 12.14) than students using the strategy that encourages only internal learning activities (M = 18.00, SD = 8.65). Students with high cognitive abilities (M = 28.75, SD = 14.42) learned on average longer than students with low cognitive abilities (M = 25.42, SD = 13.72). The differences between groups in learning time are significant ($F(1,20) = 16.67$, $p < .01$, $\eta^2_p = .46$). The learning time, however, did not significantly correlate with the post-test results.

The post-test questions were scored by two independent raters. Interrater reliability was ICC(3, k) =

0.95. Differences in the ratings were jointly settled by the raters.

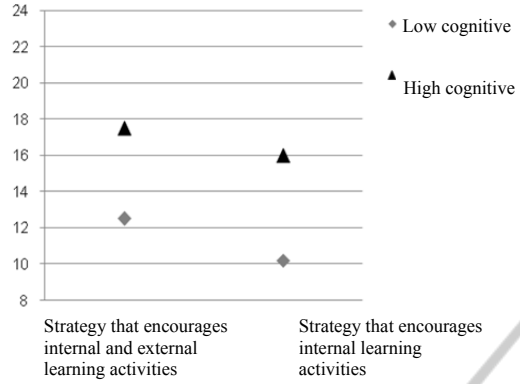

Figure 2: Overall post-test results.

The post-test results showed that the students with high cognitive abilities (M = 16.75, SD = 2.93) performed better than the students with low cognitive abilities (M = 11.33, SD = 3.11). Furthermore, students who made use of the strategy that encourages internal and external learning activities (M = 15.00, SD = 3.93) learned more than the students using the strategy that encourages only internal learning activities (M = 13.08, SD = 4.10). When the strategy groups are compared to each other at each level of cognitive ability, the students learning with the strategy that encourages internal and external learning activities outperformed the other group (see Figure 2). Similar results are found with respect to factual knowledge, conceptual knowledge, and transfer knowledge (see Table 3).

In order to determine significant differences between the groups on the post-test, a multivariate two-way analysis of variance (MANOVA) was conducted with the factor *strategy* (internal and external activities vs. internal activities) and *cognitive abilitiy* (low vs. high cognitive ability) as independent variables, and the three types of knowledge as dependent variables. The small sample sizes should be kept in mind when interpreting the data.

The analysis showed significant group differences for the factor *cognitive abilities* with respect to conceptual knowledge ($F(3,20) = 14.81$, $p < .01$, $\eta^2_p = .42$) and transfer knowledge ($F(3,20) = 8.42$, $p < .01$, $\eta^2_p = .30$). No significant differences for the factor *strategy* were found ($F(3,20) = 2.48$, $p = .13$). The effect for transfer knowledge is marginally significant ($F(3,20) = 3.90$, $p = .06$).

Table 3: The means (M) and the standard deviations (SD) on the post-test (The maximum score with respect to each type of knowledge was eight).

Strategy	which encourages internal and external learning activities				which encourages internal learning activities			
Cognitive abilities	high		low		high		low	
Type of knowledge	M	SD	M	SD	M	SD	M	SD
Factual	5.33	1.51	5.00	2.76	6.17	1.17	4.33	1.21
Concept	5.67	1.03	3.67	1.50	5.33	1.97	2.83	1.17
Transfer	6.50	1.76	3.83	2.32	4.50	.84	3.00	1.78
Overall	17.5	2.88	12.5	3.27	16.0	3.03	10.1	2.71

6.2 Analysis of the Think Aloud Protocols

In order to qualitatively determine how the students applied the strategy, the think aloud data was analyzed. The think aloud data was first transcribed and segmented into phrases. Thereafter, the phrases were associated with the corresponding learning technique. It was then analyzed to see if the technique was in fact applied. If the technique was applied, it was then judged as to whether the application took place at a surface level (e.g. selection of almost all words in the text) or at a deep level (e.g. selection of only important words in the text). All protocols were analyzed by two independent raters. Interrater reliability was ICC(3, k) = .92. Disagreements were resolved in discussion.

Deep level processing was more frequently exhibited by students with high cognitive abilities than those with low cognitive abilities. Students with low cognitive abilities processed 75% of the learning techniques at a surface level or not at all (see Table 4).

Table 4: Observed frequencies of deep and surface level processing with respect to the factors *strategy* and *cognitive abilities.*

	Strategy that encourages internal and external learning activities	Strategy that encourages internal learning activities		High cognitive ability	Low cognitive ability
Deep processing	94	39		90	43
Surface processing	90	67		70	87
No processing	8	70		32	46
Overall	192	176		192	176

Differences can also be found with respect to the strategy groups (see Table 4). The students who learned with the strategy that encourages internal and external learning activities processed more techniques at a deep level than the students who learned with the other strategy. In 40% of the cases, the students who learned with the strategy that encourages internal learning activities did not make use of any learning technique. In sharp contrast, the students who learned with the strategy that encourages internal and external learning activities almost always applied the complete strategy. Thus, promoting external learning activities seems to result in a more comprehensive use of the strategy.

At a descriptive level, the quality of the students' strategy use and the post-test results show a similar pattern. The students with high cognitive abilities outperformed the students with low cognitive abilities and the students who used the strategy that encourages internal and external learning activities learned more successfully than the students who used the strategy that encourages only internal learning activities. Furthermore, the quality of the students' strategy use correlated significantly with the post-tests results ($r = .41$, $p < .05$).

7 DISCUSSION

Two strategies for learning from texts and pictures were conceptualized and empirically evaluated in this paper. Both strategies were formed on the basis of current models of multimedia learning with the objective to foster the cognitive processes of information selection, organization, transformation, and integration.

In an experimental study, the two factors *strategy* (internal and external learning activities vs. internal learning activities) and *cognitive ability* (high vs. low) were investigated. The groups did not differ regarding age, sex, and prior knowledge. Even though the groups varied in learning time, there was no correlation between learning time and learning results. Students with high cognitive abilities performed better on the post-test than did students with low cognitive abilities. Within each ability group, students using the strategy that encourages internal and external learning activities outperformed those using the strategy that encourages internal learning activities.

In addition, the analysis of the think aloud data revealed that the quality of the students' strategy use was higher when employing the strategy that encourages internal and external learning activities. Students with high cognitive abilities, however, profited from both strategies; nevertheless, the best learning results were obtained when using the strategy that encourages internal and external learning activities. Students with low cognitive abilities, on the other hand, only learned satisfactorily when using the strategy that encourages internal and external learning activities. This strategy seems to compensate low cognitive ability, whereas the strategy that encourages internal learning activities is only advantageous under the condition of high cognitive ability.

Contrary to our expectations, the strategy that encourages internal and external learning activities did not impede the learning of students with high cognitive abilities. Even if the external activities of the students with high cognitive abilities were not more productive than those of the students with low cognitive abilities (analysis of the worksheets), the additional external activity instructions led to beneficial internal learning activities (analysis of the think aloud data). This might explain why students with high cognitive abilities also profited from the strategy that encourages internal and external learning activities.

Due to the think aloud assessment, the sample size was kept small in this study. This needs to be taken into account when interpreting the data. It was necessary, however, to acquire the process data in order to get a deeper insight into the processes that foster learning. The present study has demonstrated that the analysis of think aloud data is a promising approach to better understanding strategic information processing.

The study demonstrated that the strategy that encourages internal and external learning activities is adequate for sixth-grade students regardless of their cognitive abilities. Two other studies have demonstrated that similar strategies were also beneficial to sixth grade students learning from animation (Kombartzky et al., 2010) and text-picture-combinations (Metz and Wichert, 2009). Further research is needed to show if the proposed strategies would be advantageous for other groups of learners, as well as for other types of learning material. It would also be fruitful if future research on strategic learning would clarify the contributions of the individual learning techniques to the overall learning outcome, as well as how different combinations of learning techniques affect learning (cf. Klauer, 2010).

When thinking of learning with the computer most researchers would aspire to more complex learning environments than the text-picture-combinations described in this article. Nevertheless, many computer supported learning environments are still "just" made up of texts and pictures. Even with these "simple" multimedia materials students need a strategy to process the information adequate. If the learning environment gets more complex, effective learning strategies become even more important. Students need to be taught how to process multimedia materials just as they are taught how to understand written text. Several studies demonstrated that strategic instructions can foster learning from multimedia (e.g. Kombartzky et al., 2010; Metz and Wichert, 2009; Schlag and Ploetzner, 2011).

When developing computerized learning environments not only usability and design aspects should be taken into account, but also strategic support which helps the learners to process the presented information effectively and effeciently. This study showed that especially techniques that encourage internal and external learning activities are beneficial for the learners. Multimedia learning environments can support the use of these learning activities by providing strategic learning prompts to the learners that are integrated into the learning environment (Ruf and Ploetzner, 2012). In particular, external learning activities can be supported by providing interactive tools that allow learners e.g. to draw sketches and to take notes.

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