The Use of Learning Strategies in Learning from Text and Pictures

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Abstract: Learning material in multimedia learning environments is frequently made up of text and pictures. Many students, however, have difficulties learning from such material successfully. In order to support students’ learning, we conceptualized a deep level strategy and a surface level strategy for learning from text and pictures. In an experimental study we investigated whether students who exercised the deep level strategy subsequently learned more successfully than students who exercised the surface level strategy. No significant differences in learning success were found between students who previously exercised different strategies. In order to better understand why no differences were observable, we analyzed think aloud protocols taken from the students during learning. On the basis of this analysis we determined the strategies students actually applied during learning. In many cases students applied a different strategy than they had exercised. As expected, students who actually made use of the deep level strategy had much more learning success than students who actually applied the surface level strategy.

Keywords: learning strategies, textual and pictorial representations, think aloud protocols

Introduction

Normally, learning with the computer is equated with multimedia learning, which can be defined as: “presenting both words (such as spoken text or printed text) and pictures (such as illustrations, photos, animation, or videos)” \cite{1} (p. 2). Therefore, text and picture combinations can be understood as a fundamental form of multimedia learning. Research on text and picture combination can help to analyze multimedia learning environments.

Adding explanatory pictures to text is believed to improve learning. However, learners do not always benefit from additional pictures. \cite{2} showed that although 55\% of an average page in science textbooks is reserved for pictures, only 10\% of these pictures are explanatory pictures. These pictures are often incomplete and have no clear relation to the text. Furthermore, the processing of text and picture does not take place as easily as supposed \cite{3}. It is a cognitive challenge for learners to process and integrate the information from different representations \cite{4}. Usually, texts and pictures are presented spatially separated so that the two representations must be mentally integrated. If all relevant information is related to each other, a coherent mental representation can be constructed. But many learners are unable to relate text and picture information successfully \cite{5, 6}. Therefore, learners cannot always profit from the additional value which pictorial representations provide.

Thus, the question arises of how learning from text and picture combinations can be supported so that learners can reach deeper processing, even if the learning material is not designed in an optimal way.
1. Supporting Learning from Text and Pictures

Two general approaches to improving learning success in text and picture based learning can be differentiated. On the one hand, an improvement of the material can be attempted; on the other hand, the learner’s competences can be enhanced via learning strategies.

In recent decades, research focused on how to improve learning success in learning from text and pictures by developing guidelines for the design of external representations [1]. The underlying idea is to unburden learners from cognitive processes not directly related to learning, so that they are able to apply relevant learning processes properly. One of these guidelines is the split-attention-principle, which advises making use of spatially integrated text and picture combinations, instead of text and pictures which are presented in a spatially separated format - this reduces the effort required for visual information integration, for instance [1]. However, despite principled design of material, the achieved results sometimes fall short of expectations [7].

Until now, the use of learning strategies in processing texts and pictures has barely been investigated. Only few studies take into account learning strategies which deal with learning from texts and pictures [5, 6]. Therefore, we based our research on the well-researched field of learning strategies in relation to text understanding. In accordance with [8] we defined learning strategies as “a) a sequence of efficient learning techniques, which b) are used in a goal-oriented and flexible manner, c) are increasingly automatically processed, but d) which remain consciously applied” (p. 353, translated by the author). Two basic approaches in the field of learning strategies can be differentiated: a prescriptive approach and a descriptive approach.

The prescriptive approach supposes that four main cognitive processes are of importance to learning: selection, acquisition, construction and integration [9]. First of all, relevant information has to be selected. In order to acquire information it has to be transferred to long-term memory. In order to construct coherent representations learners have to connect information from different sources and subsequently integrate this information with prior knowledge. Cognitive learning strategies, such as rehearsal, organization and elaboration strategies support these different cognitive processes [9]. The rehearsal strategy mainly refers to processes of selection and acquisition by memorizing and repeating information. The organization strategy and the elaboration strategy are aimed primarily at selection and construction. The organization strategy is used to structure or restructure knowledge, so that information can be arranged in a meaningful external or internal representation. The elaboration strategy takes place via learning techniques such as building connections between separate information or connections between new knowledge and prior knowledge.

An example of the second type of theory is the “approaches to learning“ theory developed by [10], who descriptively identified two approaches to learning from texts. In the surface level approach/strategy learners try to memorize content by rehearsal of the information. Here, concepts and facts are memorized unreflectively by focusing on the material itself. By contrast, in the deep level approach/strategy learners try to understand the meaning by connecting separate information and focusing on relevant content. In order to elaborate on the information, a connection between prior and new knowledge is constructed.

The surface level strategy and the deep level strategy can easily be compared to the rehearsal strategy and the elaboration strategy. The rehearsal strategy, such as the surface level strategy, takes place by memorizing the information to be acquired, whereas both the elaboration strategy and the deep level strategy occur when information from different sources is integrated in one coherent model. Numerous studies show that using deep level strategies improves learning [10, 11].
The approaches discussed thus far all derive from research on text understanding. As such, they do not take processing pictorial information into consideration. But, especially the coordinated processing of text and pictures is essential for successful learning from multiple representations. Therefore, the existing learning strategy concepts have to be complemented by the use of pictorial or multimedia learning theories. We combined the learning strategy concepts with the theory of multimedia learning of [1]. Thus, the relevant aspects of learning from pictures and learning strategies were both considered.

There are three main assumptions which are important for the theory of multimedia learning [1]: the dual-channel assumption (different representations are processed in separate channels), the limited-capacity assumption (the capacity of human working memory is limited by the amount of information it can process) and the active-processing assumption (learners must actively process information in order to construct a coherent representation). In addition, [1] suggests three cognitive processes: selection, organization and integration, which are similar to the processes described by [9]. First, selection processes take place. Hereby, relevant words are selected from the presented text and relevant images are selected from the presented pictures. The selected information needs to be organized, which happens at first separately for pictorial and textual representation format. The organization process results in the construction of a verbal-textual mental model as well as a visual-pictorial mental model. These two models later have to be integrated into one coherent representation, into which prior knowledge also has to be assimilated. Only actively processed information can be stored for longer periods of time. If the selected and organized information from text and picture can be integrated into one coherent model, deep understanding of the contents can be achieved [1].

With respect to the described theories, we formulated the following two learning strategies for learning from texts and pictures. Both strategies consisted of three different processes:

The surface level learning strategy focuses on the learning material itself. Via selection and memorization, the information included in texts and pictures should be retained:

1. read the text carefully,
2. examine the picture carefully,
3. precisely remember the text and the picture.

The deep level learning strategy focuses on the content, in other words on what the material is about. Emphasis lies on the mental integration of information from different representations:

1. find the central statements of the text and the central elements of the picture,
2. clarify the relationship between the text and the picture yourself,
3. think about what was new for you and what you knew before.

Learning strategies are not personality characteristics. In fact, they depend on the task to be learned in combination with the learner’s abilities, knowledge and competence. We assume that learners often do not have stable strategies for learning from text and pictures. Usually, students are not taught these strategies in school or university. Very often, when learning with textual and pictorial material students are only able to use tactics generated ad-hoc. Hence, we expected text and picture based learning strategies to be influenceable. Therefore, we conducted an experimental study, in which we tried to teach students using one of the strategies described above. In order to demonstrate that textual and pictorial learning strategies are easily teachable, we limited the length of the practice period. Literature provides evidence that even a short introduction to learning strategies can influence learning positively [12].
2. Experimental Study

By means of an experimental study we attempted to answer three research questions:

- Can learners be instructed to use the learning strategies described above?
- Does the use of different learning strategies influence learning results?
- Are think aloud protocols an appropriate means to assess different learning strategies?

Participants were expected to use the learning strategies as practiced. In accordance with [1, 10], we hypothesized that students using the deep level learning strategy would outperform students using the surface level strategy.

2.1 Method

2.1.1 Design

In the experimental study we formed two groups. One group was instructed to use the surface level strategy, whereas the other group was instructed to use the deep level strategy.

2.1.2 Participants

Overall, 22 students (16 female and 6 male students; mean age: 24.5 (SD = 2.84)) from the University of Freiburg participated in the study, 11 in each of the two groups. Both sexes were evenly distributed across the groups. Participants were undergraduate students of education and other humanities. In order to exclude students with higher prior knowledge, students of the sciences were excluded from participation. Participation was voluntary and participants received financial compensation.

2.1.3 Material and Procedure

The study was structured into seven phases. At first, participants were introduced to the think aloud method following the suggestions of [13]. They were instructed to verbalize all their thoughts. To familiarize the students with this method they received think aloud training including a practice task. In the second phase, the learning strategies were introduced by the person directing the experiment. One group was made familiar with the deep level learning strategy, whereas the other group was introduced to the surface level learning strategy. Thereafter, participants received materials which were structurally similar to the learning material and were asked to practice the learning strategies. Participants were instructed to think aloud while practicing. On average the practice period took 20 minutes. In the third phase, participants received an introduction to the learning topic. In the forth phase, in order to assess prior knowledge, participants took a pre-test consisting of 8 items. These items were designed as four-option multiple-choice questions with only one right response per question. In the fifth phase, students used a self-rating scale on interest and self-efficacy (subclassified in the factors “challenge”, “success probability” and “failure probability”) in order to rate 19 statements along a seven-point scale [14]. The sixth phase was the learning period, during which students were asked to employ the practiced learning strategy and to think aloud. The learning material dealt with physiological processes within the human nervous system. It consisted of a combination of explanatory texts and a schematic picture, in which the picture was placed beneath the text. Learning time was not limited. In the last phase, the students worked on a post-test which consisted of 30
multiple-choice questions: 17 items on retention, 13 items on understanding. Pre-test and post-test items had the same structure.

2.2 Results

In order to test for significant group differences, we conducted a t-test. The analysis of personal data revealed that groups did not differ with regard to age (t (16.00) = .29, p = .77) and sex (8 female and 3 male in each group). The learning period took between 10 and 50 minutes, with an average time of 30 minutes. Results showed that there were no significant differences between the groups with respect to learning time (t (14.89) = -.73, p = .48). On average, participants in the pre-test answered 1.5 (SD = 0.51) out of 8 items correctly. There were no group differences with respect to prior knowledge (t (17.30) = 1.45, p = .17). Furthermore, we computed an Analysis of Variance (ANOVA), which showed that neither group differed in interest (F (1, 21) = .10, p = .75), nor in the motivation factors “success probability” (F (1, 21) = 1.51, p = .23) and “challenge” (F (1, 21) = .02, p = .90). Only for the motivation factor “failure probability” (F (1, 21) = 4.63, p = .04) could significant group differences be found. Deep level strategy learners showed a higher “failure probability” than surface level strategy learners.

Descriptive data showed that contrary to our expectations, the surface level strategy group achieved slightly better results in the post-test (cf. Table 1). There were no significant differences between both groups in the post-test (t (16.49) = .61, p = .55). The subtest results are similar to the overall test results.

Table 1: The means (M), average relative solution frequencies, and standard deviations (SD) in the post-test (in total maximum 30 points) for the strategy groups

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Surface level group</th>
<th>Deep level group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>13.45</td>
<td>3.47</td>
</tr>
<tr>
<td></td>
<td>(81%)</td>
<td>(20%)</td>
</tr>
<tr>
<td>Understanding</td>
<td>7.45</td>
<td>2.29</td>
</tr>
<tr>
<td></td>
<td>(57%)</td>
<td>(17%)</td>
</tr>
<tr>
<td>Overall</td>
<td>20.91</td>
<td>5.41</td>
</tr>
<tr>
<td></td>
<td>(69%)</td>
<td>(18%)</td>
</tr>
</tbody>
</table>

The results show that those participants who were asked to use the deep level learning strategy did not outperform participants who were asked to use the surface level learning strategy. Also, results could not be explained by the covariates. Two possible explanations may account for the results found. First, there is no relation between actual applied learning strategies and learning results. Second, there is a relation between actual applied learning strategies and learning results, but the participants did not use the strategies that were practiced before. In order to verify one of these two contradictory explanations, think aloud protocols were analyzed.

2.3 Analysis of the Think Aloud Protocols

In the first step, think aloud protocols were transcribed and segmented into semantic units. The semantic units were assigned to one of four categories:
Surface level strategy statements (e.g., reading the text, identifying elements in the picture, memorizing text and picture ...);

Deep level strategy statements (e.g., using information from the text to explain the picture or vice versa, constructing a coherent mental model of all relevant information, drawing conclusions ...);

Metacognitive statements (e.g., explaining the next steps, stating misunderstandings ...);

Rest category (e.g., cognitive processes not related to learning processes, statements that do not make sense).

All protocols were categorized by two independent analysts. The agreement in this rating amounted to 89.2%. Disagreements were resolved in discussion. Data from the protocol analysis showed that learners used surface level strategy statements most frequently (M = 57%; std. = 16%), compared to deep level strategy statements (M = 20%; std. = 11%) and metacognitive statements (M = 22%; std. = 8%). Only a few statements fell into the ‘rest category’ (M = 1%; std. = 1%).

Based on the protocol analysis, the participants were redistributed into new learning strategy groups. There are several theoretical assumptions which suggest that the deep and surface level strategies mainly differ in the frequency of using deep level strategy statements or cognitions [15]. We expect that deep level strategy learners first execute surface level processes before a deeper processing can occur, whereas surface level strategy learners are expected to stay on a surface level during information processing. Therefore, a median-split based on the percentage of deep level strategy statements was conducted. Students who used more than 24% deep level strategy statements were referred to the deep level strategy group.

Students of the newly formed deep level strategy group expressed on average 30% deep level strategy statements, whereas students of the newly formed surface level strategy group expressed on average only 10% deep level strategy statements. Again, each group consisted of 11 participants. The comparison between the experimental groups and the newly formed groups showed that only 8 members out of 22 participants (4 of each group) made use of the learning strategy they practiced before.

This means that only a small number of participants actually applied the learning strategy they were asked to use. Therefore, our hypothesis that it is possible to influence the use of learning strategies by such a short practicing period needs to be rejected. To gain insight into the relations between learning strategies and learning outcome, the newly formed groups were further analyzed.

2.4 Analysis of the Newly Formed Groups

Because of the post-hoc formation of the strategy groups, a new analysis of group constitutions was necessary. The analysis revealed that groups did not differ with regard to age (t (13.29) = -.15, p = .89), sex (8 female and 3 male in each group) or learning time (t (18.47) = -1.10, p = .28).

On average participants gave 1.5 (SD = 0.51) correct answers in the pre-test. The t-test showed that students of the deep level strategy group gave significantly more correct answers than students of the surface level strategy group (t (14.09) = -2.67, p = .02).

An ANOVA revealed significant differences for the factors interest (F (1, 21) = 8.26, p = .01) and “success probability” (F (1, 21) = 8.94, p = .01), but not for the factors “challenge” (F (1, 21) = 1.67, p = .21) and “failure probability” (F (1, 21) = 3.38, p = .08). Deep level strategy learners showed significantly higher interest and “success probability” than surface level strategy learners. Furthermore, for the overall post-test, a high correlation
was found between the three motivational factors interest \((r = .66, p = .00)\), “success probability” \((r = .81, p = .00)\) and “challenge” \((r = .52, p = .01)\).

The post-test results showed that the deep level strategy learners achieved better results (cf. Table 2). Deep level strategy learners outperformed surface level strategy learners in retention as well as in understanding. On average, they answered 10 questions (5 in retention and 5 in understanding) more than the surface level strategy learners.

**Table 2:** The means (M), average relative solution frequencies, and standard deviations (SD) in the post-test (in total maximum 30 points) for the newly formed strategy groups

<table>
<thead>
<tr>
<th>Concepts</th>
<th>Surface level group</th>
<th>Deep level group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention</td>
<td>10.18 (61%)</td>
<td>15.36 (92%)</td>
</tr>
<tr>
<td></td>
<td>4.30 (25%)</td>
<td>1.62 (8%)</td>
</tr>
<tr>
<td>Understanding</td>
<td>4.81 (37%)</td>
<td>9.45 (73%)</td>
</tr>
<tr>
<td></td>
<td>2.85 (21%)</td>
<td>1.50 (11%)</td>
</tr>
<tr>
<td>Overall</td>
<td>15.00 (50%)</td>
<td>24.91 (83%)</td>
</tr>
<tr>
<td></td>
<td>6.91 (23%)</td>
<td>2.98 (10%)</td>
</tr>
</tbody>
</table>

In order to take into consideration the influence of covariates, an Analysis of Covariance was computed, whereby the newly formed strategy groups served as the independent variable, interest, “success probability”, “challenge” and prior knowledge as covariates, and the overall post-test result as dependent variable. The analysis yielded a significant main effect for the strategy group \((F (1, 21) = 7.23, p = .02)\). Furthermore, significant effects were found on the covariates “success probability” \((F (1, 21) = 16.05, p = .00)\) and “challenge” \((F (1, 21) = 5.13, p = .04)\). The variables strategy group, “success probability” and “challenge” explained most of the variance \((R\text{-square}, p = .81)\).

The results show that students who actually made use of the deep level strategy had much more learning success, taking into account motivational factors and prior knowledge, than students who actually applied the surface level strategy.

### 3. Conclusions

When learning with the computer, learners are often confronted with text-picture combinations or even more complex multirepresentational learning material. It is known that learners very often have difficulties in processing text and pictures [3]. Therefore, we tried to improve learning by providing learners with a short exercise in making use of two different learning strategies. Our study showed that neither deep level strategy learners nor surface level strategy learners adopted the practiced strategies. This may be due to the short duration of the exercise. Participants seem to display more stable learning habits as supposed, so that the strategies were not learned as easily as expected.

However, the analysis of process data indicates that it is possible to differentiate between different learning strategies. As assumed, learners who took advantage of the deep level strategy achieved a significantly higher learning outcome than those learners who applied the surface level strategy. Deep level strategy learners were also more interested, more motivated and had slightly higher prior knowledge than surface level strategy learners. It could be a lack of prior knowledge, interest and motivation which prevents surface level strategy learners from achieving deeper information processing [18].

For further research, our study suggests various modifications, which could help improve the teaching and exercising of learning strategies. Because of already available
learning habits, it might be necessary to provide the opportunity to practice the strategies extensively, so that learners become skilled in the use of learning strategies [16]. It seems to be important that learner’s prior knowledge is sufficient enough in order to effectively support the use of deep level strategies. Experts-novices research shows that experts are characterized by a high prior knowledge and elaborate strategies, which depend on one another [17]. We might be able to assume that only if it is possible to teach learners both relevant knowledge and strategical information, that they will be able to internalize learning strategies for deeper processing. Furthermore, the results also suggest that it could be fruitful to expand the strategies via components for self-motivation and self-regulation [18].

Overall, however, it remains a challenge to support multimedia learning in such a way that learners routinely engage in deep processing of the texts and pictures presented.

References