THE USE OF ADDITIONAL INFORMATION IN PROBLEM-ORIENTED LEARNING ENVIRONMENTS

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The Use of Additional Information in Problem-oriented Learning Environments

Abstract

Self-directed learning with authentic and complex problems (problem-oriented learning) requires that learners observe their own learning and use additional information when it is appropriate – e.g. hypertextual information in computer-supported learning environments. Research results indicate that learners in problem-oriented learning environments often have difficulties using additional information adequately, and that they should be supported. Two studies with a computer-supported problem-oriented learning environment in the domain of medicine analyzed the effects of strategy instruction on the use of additional information and the quality of the problem representation. In study 1, an expert model was used for strategy instruction. Two groups were compared: one group with strategy modeling and one group without. Strategy modeling influenced the frequency of looked-up hypertextual information, but did not influence the quality of learners' problem representations. This could be explained by difficulties in applying the general hypertext information to the problem. In study 2, the additional information was presented in a more contextualized way as graphical representation of the case and its relevant concepts. Again, two groups were compared: one with a strategy instruction text and one without. Strategy instruction texts supported an adequate use of this graphical information by learners and had an effect on the quality of their problem representations. These findings are discussed with respect to the design of additional help systems in problem-oriented learning environments.

The Use of Additional Information in Problem-oriented Learning Environments

Theoretical Background

With the constructivist turn in instructional research and the view of learning as an active, self-directed and highly situated process, problem-oriented learning has recently had a kind of renaissance (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Cognition and Technology Group at Vanderbilt, 1992, 1993; Collins, Brown, & Newman, 1989; Resnick, 1987). The main idea of problem-oriented learning is that knowledge acquired in the context of meaningful and authentic problems can more easily be transferred to real-life situations than knowledge acquired in an abstract and systematic way. Of course, the idea of teaching applicable knowledge through learning with authentic and complex problems has a long history: For example, at the end of the 19th and at the beginning of the 20th century, the 'Reformpädagogik' (reform pedagogy) designed and implemented instructional models which resemble the constructivist view of learning and teaching (e.g. Gaudig, 1922; Kerschensteiner, 1912; see Mandl, Gruber, & Renkl, 1996).

Problem-oriented learning environments

This paper deals with self-directed learning in problem-oriented learning environments in the domain of medicine. These learning environments can be characterised by the following features: (1) The learning environments contain authentic problems which learners have the task to solve. In medicine, students deal with medical cases and are required to give diagnoses. The problems should present a good amount of information that is not necessarily relevant for the solution, because 'problem finding' and the selection of the relevant information is very important for solving the realistic problems (see Cognition and Technology Group at Vanderbilt, 1992, 1997; Williams, 1992). Computer programs are particularly suitable for the illustration of authentic and complex problems: On the one hand, the use of multimedia elements (pictures, sounds, graphics) allows the depiction of the cases to be very close to reality. On the other hand, the illustration of cases with computers enables learners to interactively work on the case. In that way, they may for example decide, which data from a patient's medical history to ask for or which physical examinations to take. (2) The second main characteristic of problem-oriented learning environments is that students solve the problems in a self-directed manner. Thus, learners – to the extent that is possible – work with a minimum amount of external control. By working almost independently in problem-oriented learning environments, existing knowledge is first applied to the problem and then, through this application, changed in its structure. Bereiter and Scardamalia (1989) called this process "learning through problem-solving": The application of knowledge facilitates processes, in which prior knowledge from different areas is connected and restructured. Research on medical expertise stresses that the exposure to case problems and the extensive and repeated application of knowledge is the main cause for the restructuring of knowledge during the development of expertise (Boshuizen, Schmidt, Custers, & van de Wiel, 1995; Schmidt & Boshuizen, 1993). First, by the use of declarative knowledge when solving cases, its structure becomes entrenched in concepts with a higher level of efficiency and practicality, which is labelled "knowledge encapsulation" (Schmidt & Boshuizen, 1993). Second, the exposure to case problems leads to the development of "illness scripts", a knowledge structure containing a wealth of clinically relevant information about a disease, its consequences and enabling conditions (context in which the illness develops). Yet, problem-oriented learning exceeds the modification of existing knowledge through application. If a learner becomes aware of not being able to solve a problem with his or her present knowledge, he or she needs to extend this knowledge, for example by drawing on additional information offered in the learning environment. Altogether, problem-oriented learning is particularly appropriate for the advanced acquisition of competence (Spiro, Feltovich, Coulson, & Anderson, 1989) that emphasizes the contextualization and extension of existing knowledge. Computer-based problem-oriented learning environments can thereby either be implemented in university courses or offered for self-directed learning.

Problem-oriented learning needs to be distinguished from problem-based learning, which can also be seen as "learning as problem-solving", following Bereiter and Scardamalia (1989). In problem-based courses in medicine, a clinical case serves as starting point for a study session of several hours in a small group led by a tutor. Problem-based learning is therefore characterised by the use of problems as a context for students to acquire knowledge about basic and clinical sciences and problem-solving skills (e. g. Albanese & Mitchell, 1993; Dolmans, 1994). After stating the main learning objectives on the basis of a special case, students have the opportunity to look for suited information (e. g. textbooks or other media), apply newly gained knowledge to the problem and summarize what has been learned (Barrows, 1985). The learning process concludes with the students evaluating the information resources they used. What distinguishes problem-based learning from problem-oriented learning, is that in problem-based learning the problem is presented first, before students have learned basic science or clinical concepts, not after (Barrows, 1986). Furthermore, learning activities last for several weeks. Finally, the intensive support of students by tutors in conducting learning activities is pivotal for problem-based learning. Empirical findings concerning the use of additional information in computer-based problem-oriented learning environments can therefore not be transferred to problem-based learning.

The use of additional information in problem-oriented learning environments

In problem-oriented learning environments students learn through self-regulated learning with authentic cases. Therefore, they have to observe their own problem-solving processes and correct themselves when necessary. Hence, self-regulated problem-solving means that it is crucial to control one's own actions and to use the relevant metacognitive control strategies in problem-oriented learning environments.

Based on the research on metacognition, Collins et al. (1989) describe an adequate use of control strategies in problem-oriented learning environments: When learners work on the problems, they have to monitor their own learning, i.e. they have to observe and evaluate their own learning processes. As long as no difficulties arise (positive monitoring, see Chi, Bassok, Lewis, Reimann, & Glaser, 1989), the application of further control strategies is not necessary. However, as soon as the learner (negative monitoring) notices obstacles, contradictions, or comprehension failures, the application of further control strategies becomes important. Learners then have to specify the cause of the obstacle or comprehension failure. If the learner considers the cause to be a lack of competencies, self-regulation is necessary. It may be sufficient to consciously activate prior knowledge and try for the solution a second time in order to overcome the obstacle. Yet, in many cases prior knowledge may not be sufficient, and in these situations a comprehension failure should lead to the use of additional information. In computer-based learning environments, a very common way to offer additional information to students includes the use of hypertext systems.

On the one hand, the use of further information in a problem-oriented learning environment contributes to the elimination of comprehension failures. On the other hand, an adequate use of information plays a key role in the acquisition and refinement of knowledge. But this form of "impasse-driven learning" only occurs when learners use the additional information appropriately. First, among all the sources, learners have to find specifically the information relevant for 'repairing' the comprehension failure. In a second step, the information must be applied adequately to the problem.

Learning with a computer-based case can be conceptualized as a construction of a problem-representation containing the case information as well as biomedical or pathophysiological knowledge (see Gräsel, 1997). When learners notice that their problem-representation is not adequate or complete, they need to use additional information as a basis for changing or refining their problem-representation. This requires the abstract information to be contextualized with the specific requirements of the given case. Therefore, an adequate use of additional information should help students in constructing elaborated and correct problem-representations of the given case, and support them to connect knowledge from different areas. This process can be illustrated with an example: A case consists of a pale looking pregnant woman who complains about fatigue. On the basis of the case information the learner constructs a problem-representation with possible causes for the symptoms. In his/her view, the most likely diagnosis is an anemia due to iron deficiency caused by a poor diet. But he/she notices that he/she is not sure about whether and how pregnancy influences iron deficiency. Therefore, the learner uses hypertextual information in the learning environment and gets the information in question. In order to profit from this information, he/she has to think about what the information means for the given case, e. g. whether the information increases or decreases the probability of various hypotheses.

Proponents of problem-oriented learning implicitly assume that learners master the self-regulated use of additional information. They state that comprehension failures are the starting point for the use of additional information (see Prawat, 1993). To what extent students succeed in self-regulation during the process of problem-oriented learning has barely been investigated up to this point.

Research on metacognition shows that the adequate use of control strategies is often difficult for learners (e.g. Schneider & Pressley, 1989). Several studies have shown that even experienced and adult learners are not successful in assessing their comprehension and correcting their method of learning accordingly (Glenberg & Epstein, 1985; Pressley, Snyder, Levin, Murray, & Ghatala, 1987). Additionally, in research on learning with technologies it was found that hypertext information in computer-based learning is rarely used by students. Also, it occurs that information in individual hypertext pages is processed superficially and that learners tend to "jump" from page to page and sometimes get "lost in hyperspace" (Dillon & Gabbard, 1998; Jonassen & Mandl, 1990). To summarize, research indicates that it is rather optimistic to assume that learners can adequately control their proceedings in computer-based problem-oriented learning environments. As a consequence, these learning environments should be designed in a way that supports learners in their use of control strategies: Learners should be assisted in order to notice their comprehension failures and in to use the given additional information when necessary.

Recently, instructional researchers proposed instructional methods to support the use of adequate strategies (Cognition and Technology Group at Vanderbilt, 1997; Collins & Brown, 1988; Collins et al., 1989). One aspect these methods have in common is that strategies are taught in a contextualized manner. Research on the training of learning strategies stresses the importance of being familiar with the conditions for the use of the strategies (i.e. Paris, Lipson, & Wixson, 1983; Friedrich & Mandl, 1992). Learners not only receive hints about which strategies they should use; they are also informed about how they should concretely handle the strategies in the context of a specific problem and under which conditions the implementation of the strategies is useful.

In the Cognitive Apprenticeship approach (Collins et al., 1989), the instructional method of strategy modeling is recommended: An experienced practitioner shows how to adequately learn with complex and authentic problems. Concerning control strategies, an expert-model shows how a practitioner deals with obstacles or comprehension failures. This can either take place through the mindful activation of prior knowledge or the use of external additional information. Other instructional models use strategy instruction texts as a form of support (Fischer, Gräsel, Kittel, & Mandl, 1997; Stark, Graf, Renkl, Gruber, & Mandl, 1995): The students receive short texts that describe the use of the strategies step by step. Of course, instruction texts are widely used in educational settings for different purposes. However, in the constructivist approaches to problem-oriented learning they are utilized more specifically: They invite learners to adequately apply strategies in a given problem-oriented learning environment and therefore support the contextualized use of strategies.

Findings show that, in general, problem-oriented learning environments are suited to foster the acquisition of applicable knowledge (e. g. Cognition and Technology Group at Vanderbilt, 1997). Nevertheless, it can be assumed that supporting an adequate use of control strategies – especially the use of additional information – can enhance the effectiveness of problem-oriented learning environments.

Studies

General Research Questions

We conducted two studies with the following general research questions: (1) To what extent does strategy instruction effect the use of additional information in problem-oriented computer-based learning environments? (2) Is there a correlation between the use of additional information and the quality of the problem representation?

Learning Environment

Both studies were carried out in the domain of medicine. For a learning environment we used the multimedia learning system 'PlanAlyzer' (Lyon et al., 1990). The cases presented in the program deal with anemia (the lack of hemoglobin). Learners take on the role of a physician, who should come up with a diagnosis for a case and should initiate the appropriate therapy. In the first step, they obtain information on the main complaints of the patient. Then they get access to medical history data. In the next step, learners have the opportunity to conduct a physical examination. Finally, they receive laboratory findings and can observe a smear from the patient, as through a microscope to determine to what number the different cell types are present.

Study 1

A central element of successful self-regulated learning in a problem-oriented learning environment is to control the own learning activities and use additional information when prior knowledge is not sufficient for dealing with the problem. In the first study, we investigate the effect of strategy modeling on the use of control strategies. Two research questions are pursued:

(1) Can strategy modeling promote the use of control strategies in problem-oriented learning environments? It can be expected that strategy modeling leads to a better self-regulation during learning. When comprehension failures and mistakes arise, learners should more often try to use additional information or their prior knowledge to correct them. Accordingly, strategy modeling should lead to less frequently ignoring comprehension failures and obstacles.

(2) Does a correlation exist between the use of control strategies and the quality of the problem representation? It can be presumed that the self-regulation of mistakes – either with additional information or the reapplication of prior knowledge – is positively correlated with the quality of the problem representation. In contrast, a negative correlation can be expected between ignoring mistakes and a well-elaborated and correct problem representation.

Method

Design. 24 fourth year medical students participated in the study. All students were enrolled in the traditional curriculum at the University of Munich. The students were going through a clinical period of their studies and had therefore already made some experiences with case-based learning. Only students who had completed all courses dealing with anemia were asked to participate. After a pretest – factual knowledge of anemia and solutions of short paper-and-pencil cases – learners were introduced to the PlanAlyzer program. Next, all participants had to solve a baseline case without instructional support. Afterwards, the whole group was divided into two groups who worked with the treatment case under the following conditions: Strategy modeling (n = 12) and control group (n = 12).

Finally, learners had to work with a transfer case by themselves. The baseline and the treatment case were very similar (anemia due to iron deficiency), but the transfer case differed concerning the findings, the hypotheses, and the underlying concepts (anemia due to leukemia). The two groups were comparable in their learning prerequisites: There were no differences in the results of the pretest. Furthermore, students in both groups showed a comparable use of control strategies in the baseline-case.

Additional information. The PlanAlyzer contains three hypertextual forms of additional information which were used in study 1: (1) A glossary: The students can call on illustrated texts about several terms in the hypertext system. (2) A diagnostic help: The students are given important hints for the physical examination in form of a short text. (3) A database of blood smear: Learners can request information from a picture database, which contains several smears in order to compare them with the one of the patient.

Strategy modeling. Learners in the treatment group were exposed to the model of an expert (experienced physician) who articulated her reasoning while diagnosing a case of the PlanAlyzer; additionally, learners saw how the expert dealt with the case on the computer screen (e. g. which kind of information the expert asked for). The expert explained how she advanced in her diagnosis of anemia. For example, she articulated what symptoms she looked for, or how she interpreted the symptoms in reference to differential diagnoses. She also showed how she corrected her comprehension failures and handled obstacles. Concerning the use of control strategies, she emphasized that every comprehension failure should be tackled and not ignored. She also demonstrated that either one's own knowledge or additional information can be called upon for corrections. Subjects in the control group worked on the same case without instructional support; time on task was equal in both groups (60 minutes).

Assessment of the use of control strategies. In many studies, strategies are assessed by questionnaires after learning. Yet, this kind of reflective self-evaluation has some methodological problems (e.g. biases in self-assessment). Therefore, we decided to measure the use of control strategies during the learning process. Learners were asked to think aloud while working on the cases. Think-aloud protocols of the transfer case were analyzed with regard to the strategy use. In the first step, all text sequences that indicated an evaluation of one's own proceedings were highlighted. The following forms of control strategies were distinguished: (1) The use of additional information: The students notice a comprehension failure, accept that the mistake stems from a lack in their own knowledge and correct it by using the help systems (e. g. "Pica – I've never heard that. I better look it up."). (2) Applying prior knowledge: A mistake can be corrected through the mindful activation of prior knowledge (e. g. "I have to remember the last lecture about anemia – I guess we had a similar case there. Let me think about that..."). (3) Ignoring: A problem is noticed, but no attempt towards correction takes place (e. g. "I do not understand why the smear looks quite normal. I'll go on anyway."). (4) Positive monitoring: Supplementary, the sequences in which the students remark that they have learned or understood something were coded (e. g. "I think I'm doing much better than before.").

Quality of problem representation. Before students gave the final diagnosis at the end of a case, they were asked to verbally summarize the case. The students were requested to explain how they made their diagnosis and for what reasons other hypotheses were ruled out. This oral summary was audio-taped and transcribed. The transcription of the summaries was used as data source for the measurement of the quality of the learners' problem representation. The quality of the problem representation not only means whether or not the learners succeeded in making the right diagnosis at the end of a case. Moreover, it was taken into account, how elaborated and correct their explanations for their diagnosis and differential diagnoses were. For this purpose, a physician analyzed all summaries with regard to how the various hypotheses about the case were grounded on the data and the biomedical and pathophysiological concepts. In assessing the quality of the problem representation, the number of hypotheses and medical concepts was considered that were correctly related with the explanations. For example, if learners correctly founded 4 appropriate diagnoses on 12 medical concepts in their summary, they would reach a score of 16.

The degree to which control strategies were used, as well as the quality of the problem representation were obtained from the analysis of verbal data. Since interval scale data level can not be assumed, we took the Mann-Whitney-U test, for the comparison of the groups; for testing the correlation, we used Spearman's correlation coefficient. An alpha level of .05 was used for all statistical tests.

Results

Research question one: Effect of strategy modeling on the use of control strategies.

Before the treatment, there were no differences between the two groups: They were comparable both in prior knowledge and in their use of control strategies in the baseline case. After they received the strategy instruction, however, there were differences between the groups (Table 1): Learners in the group with the strategy modeling used the additional information to correct their comprehension failures more frequently. Moreover, they applied prior knowledge more often to tackle their comprehension failures. Finally, the expected difference could be found regarding the ignoring of obstacles: Learners in the control group ignored mistakes more frequently than learners in the group with strategy modeling. Regarding positive monitoring, no differences were found between the groups.

Table 1 approximately here

Research question two: Correlation between the use of control strategies and the quality of the problem representation. Table 2 shows that the expected correlation did not appear. Neither the frequency in the use of additional information nor the application of prior knowledge correlated with the quality of the problem representation (quantity of correct hypotheses and underlying medical concepts) to a substantial degree. Moreover, data do not confirm that the amount of ignored comprehension failures correlates negatively with an elaborated problem representation. Additional analyses show that strategy modeling had no effect on the quality of the problem representation (mean rank strategy modeling (n = 12): 13.13; mean rank control group (n = 12): 11.88; U = 64.5; n. s.).

Table 2 approximately here

Discussion

The results of study 1 show that strategy modeling can influence the frequency of error regulation positively. However, this seems to have no effect on the construction of the problem representation: Neither the use of additional information nor the application of prior knowledge correlated with the quality of the problem representation. Moreover, the subjects' problem representations in the two groups were comparable regarding their quality.

Concerning the use of additional information, it can be presumed that learners, even with the help of strategy modeling, do not succeed in using the information from hypertexts for the construction of the problem representation. In the strategy modeling group, the learners were taught how information from the hypertext system can be applied to the case. It is possible that this form of support is not sufficient for the learners to be able to correctly apply the general and systematic information to the context of a concrete problem. If the learners do not succeed in contextualizing the information – with or without the use of strategy modeling – then the question arises, whether this form of additional information in computer-based problem-oriented learning environments is really helpful to learners. It is possible that many learners feel over-challenged in applying general text information to problems and in establishing connections between general information and concrete problems. It can be assumed that the additional information in computer-based learning environments should thus have a stronger relation to the problem, accenting the relations between concepts and case information in particular. Such a form of additional help was investigated in the second study.

Study 2

In the second study, an information system was developed which avoids the shortcomings of hypertext and supports the learners in the contextualization of the information. The additional information used in this study offers the information graphically, such that concepts and especially the relations between concepts are visualized. Like in study 1, the question was whether strategy instruction has an effect on the use of additional information. In study 2, we focused on the manner in which learners use additional information. We distinguished three forms: adapting, ignoring or declining information. The research questions of study 2 are: (1) Does strategy instruction have an impact on the learning process in such a way that learners more often adapt additional information, and less often ignore or decline it? (2) Does a positive correlation exist between an adaptive use of information and a high quality of the problem representation on the one hand, and a negative one between the ignoring or declining of additional information and a high quality of the problem representation on the other?

Method

Design. 12 fourth year students participated in study 2. Regarding their learning requirements, the subjects are comparable to those in the first study. As in the first study, a prior knowledge test was taken. Afterwards, students were introduced to the use of the PlanAlyzer software. After a baseline case without strategy instruction, learners worked on two cases under two experimental conditions. In the experimental group, they were provided with graphical information and strategy instruction; in the control group they received the graphical information without strategy instruction. The two groups were comparable in their prior knowledge as well as in their strategy use in the baseline case.

Additional information. Additional information was offered to the learners in the form of graphics (a type of concept map) that contained information on the case (symptoms) as well as possible diagnoses. Additionally, the concepts included in the graphical information could be looked up in a hypertext system. In the following four steps of the diagnostic procedure, the learners were automatically shown the graphical information: the main complaints, the medical history, the physical examination, and the findings in the laboratory. Moreover, students had access to the graphics of the current stage. With each step, the graphics contained more information– suitable to the corresponding step in the program (As an example, figure 1 shows the graphical information after the laboratory tests). In both groups, subjects were provided with a mapping tool that helped them visualize their own solution of the case. The students' mapping tool used the same symbol system as in the expert maps (Fischer, 1998; Jonassen, Beissner, & Yacci, 1993). This allowed the subjects to compare the graphical information with their own solution.

Figure 1 approximately here

Strategy instruction texts. For strategy instruction, the learners were given short texts. These texts explained how to use the graphical information for learning, and why it is wise to use it. It was especially suggested that learners compare their own solution with the expert solution and that they correct their solution according to the model of the expert.

Assessing the use of the graphical information. Learners were asked to think aloud while they worked with the graphical information. Think-aloud protocols were analyzed regarding the way learners used the graphical information. If the subjects discovered a difference between their solution and the graphical information and thereafter corrected their interpretation appropriately (verbally or by changing their map), an adapting use was coded (e. g. "I didn't think of this hypothesis. I'll change my map."). Ignoring was coded, if the difference between the correct interpretation and one's own solution was not at all considered in the learners' further proceedings. Finally, the information could also be declined; in this case learners questioned the correctness of the graphical information (e. g. "The expert thinks of anemia due to iron deficiency. I believe he's wrong.").

Quality of problem representation. As in study 1, at the end of a case learners were asked to summarize the case and to explain their own diagnoses and differential diagnoses.

These case summaries were transcribed and analyzed by a physician. Comparable to study 1, a physician analyzed the summaries with respect to the justifications of the suggested diagnoses. We determined the number of adequate hypotheses and each medical concept that was correctly mentioned in the learners' explanations.

Results

Research question one: effect of strategy instruction on the use of additional information. The group with the strategy instruction differed from the control group in the process of using the graphical information (Table 3): Subjects in this group were more likely to integrate the graphical information into their own solution. As expected, they also ignored the graphical information less frequently. Concerning declining information and positive monitoring, there were no differences between the groups.

Table 3 approximately here

Research question two: Correlation between the use of additional information and the quality of the problem representation. Data are consistent with the assumption that the quality of the problem representation increases when graphical information is adapted. It could also be confirmed that ignoring the additional information is negatively related to the quality of the problem solution (Table 4).

Table 4 approximately here

Discussion

The strategy instruction in this study lead to changes in how the graphical information was used by the learners: The information was more frequently used for constructing the problem representation and less often ignored. As expected, the quality of the problem representation is positively correlated with adapting information. Accordingly, it is negatively connected with ignoring deviations.

The effectiveness of strategy instruction in this study can be explained as followed: Without support, the learners have problems in using and interpreting the graphical information adequately. Therefore, the information is often ignored or only partly used to solve ones own problem. Strategy instruction texts can stimulate the learners to use control strategies in computer-based learning environments, especially to compare their solutions with the graphical information. This leads to a detection of mistakes and comprehension failures, and it has consequences for the quality of the problem representation. The study indicates that an adaptive use of additional information in problem-oriented learning environments has an effect on the quality of learning. However, because of the small amount of participants, further research on this topic is needed.

General Discussion

The two studies dealt with the question of how additional information can be used in problem-oriented computer-based learning environments. A fundamental idea of problem-oriented learning is that learners should be self-regulated and restricted only to a small degree by teachers or instructors. If their prior knowledge does not suffice for solving the problem, they can draw on additional information and use it to correct their comprehension failures and broaden their knowledge. The studies made the assumption that it might be too optimistic that learners can succeed in this demanding self-regulation process.

The results confirm our assumptions: It cannot be assumed that the independent work with computer-presented authentic and complex problems leads to an appropriate self-regulation as far as the use of additional information in form of hypertext is concerned. Either the participants used this information only to a small extent, or they were not successful in correctly applying the information in the context of the given problem. It is crucial for the use of additional information in problem-oriented computer-based learning environments that the abstract information is applied to a concrete case. The results of study 1 lead to an even more pessimistic conclusion: Our findings lead us to suspect that the processes of contextualizing information were not mastered by the subjects in the experiment– even if they used additional information. This assumption should nevertheless be investigated in further studies.

If additional information is offered in relation to the current problem, it can be used more effectively. In study 2, learners received no hypertext system for additional help; instead they were given a graphical representation of information relevant to the problem. The graphical format especially stresses the relations of the information to aspects of a concrete case. Nevertheless, this form of contextualized information can be used by learners more effectively if accompanied by additional strategy instruction.

The following consequences can be drawn from the findings of the two studies: Additional information could only be used adequately by the students, when it was presented in a contextualized manner and when students were supported by strategy instruction on how to use the information. This has consequences regarding the design of problem-oriented, computer-supported learning environments:

(1) One can assume that extensive hypertext systems are not as helpful for learners as they are supposed to be (see also Dillon & Gabbard, 1998). The designers of learning environments often commit a lot of time and effort to the development of hypertext systems. The question arises, whether this effort should not better be invested in the development of other forms of information or help systems.

(2) The data of both experiments show that even advanced learners – fourth year medical students – have difficulties in adequately using information without instructional support. These findings could have consequences for the development of problem-oriented learning environments: Instructional designers can not rely on learners recognizing and correcting their mistakes when learning individually. Problem-oriented learning environments should support these metacognitive control strategies either through contextualized strategy instruction or through implementing these computer-based learning environments into curricular courses.

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Key words

Control strategies, hypertext, problem-oriented learning, strategy instruction

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Table 1

Comparison of Control Strategies between the two Experimental Groups (mean ranking)

	Experimental group			
	Strategy modeling	Control group		
Control strategy				
	Mean ranking	Mean ranking	U	p
Using additional help	15.88	9.13	31,5	< .01
Applying prior knowledge	16.13	8.88	28.5	< .01
Ignoring	9.58	15.42	37.0	< .05
Positive monitoring	13.42	11.58	61.0	n.s.

Note. Strategy instruction (n = 12); control group (n = 12).

Table 2

Correlation between the different forms of control strategies and the quality of the problem representation (N = 24)

Control strategies	Spearman correlation with the quality of the problem representation
Using additional help	-.09
Applying prior knowledge	-.00
Ignoring	.19
Positive Monitoring	.12

Table 3

Comparison of different forms of the use of information between the two experimental groups

	Experimental group			
Use of information	Graphical help with strategy instruction text	Graphical help only		
	Mean ranking	Mean ranking	U	p
Adapting	8,17	4,83	8,0	< .10
Declining	6,58	6,42	17,5	n.s.
Ignoring	4,08	8,92	3,5	< .01
Positive Monitoring	5,67	7,33	13,0	n.s.

Note. Graphical help with strategy instruction text (n = 6); graphical help only (n = 6).

Table 4

Spearman correlation between the use of information and the quality of problem representation (N = 12)

Use of information	Spearman correlation with the quality of the problem representation
Adapting	.58*
Declining	-.28
Ignoring	-.52*

Figure Caption

Figure 1. Example of a graphical information in study 2 (after the fourth step "laboratory test" of the PlanAlyzer). Hypotheses as well as relevant findings are visualized with their interrelations.