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LEARNING FROM WORKED-OUT EXAMPLES: THE TRANSITION FROM INSTRUCTIONAL EXPLANATIONS TO SELF-EXPLANATION PROMPTS

Abstract. A recent study on example-based learning revealed that instructional explanations provided in addition to self-explanation prompts can impair learning results. Additionally, Education students in different programs (didactically-oriented versus subject matter-oriented) differed in their learning outcomes. In this study we intended to find a favourable combination of instructional explanations and self-explanation prompts. Thereby, differences of potential target-groups were taken into account. Forty-eight students of Education were taught by two different learning conditions of a computer-based learning environment how to effectively design learning materials: (1) learning was fostered only by self-explanation prompts, (2) instructional support changed during the course of learning from instructional explanations to self-explanation prompts. The results showed that Education students from a subject matter-oriented program achieved the highest learning outcomes in the combined condition. Future teachers from a didactically-oriented program learned most successfully by being supported by self-explanation prompts only. Both groups clearly preferred the combined condition.

1. INTRODUCTION AND THEORETICAL BACKGROUND

Worked-out examples consist of a problem formulation, solution steps, and the final solution. They are of major importance for initial skill acquisition in well-structured domains (for an overview see Atkinson, Derry, Renkl, & Wortham, 2000). Exploiting the potential of learning with worked-out examples means that several examples are provided before problem solving in order to foster understanding.

Teachers using worked-out examples in their classrooms have to know how to effectively employ these examples. Therefore, we designed a computer-based learning environment in which future teachers learned about how to design and combine worked-out examples by studying instances of well- and poorly-designed worked-out examples or example sets. The examples of well- or poorly-designed worked-out examples are called *solved example problems*; they do not contain the solution steps showing how to get to a well-designed worked-out example.

Former studies showed the benefits of such a computer program (Schworm & Renkl, 2002). The learning environment focused on two selected features of example design and combination. First, it was taught that worked-out examples containing pictorial as well as textual information should be constructed to maximally integrate all sources of information into one source *(integrated format).* This avoids a cognitive overload caused by the splitting of the learner's attention (Sweller, van Merriënboer, & Paas, 1998).

A second aspect taught by the learning environment is the effective combination of multiple examples. When dealing with different but interrelated problem types, multiple examples should be combined such that the relevant structural features become obvious. This can be achieved by creating a *structure-emphasizing example* *set* (Quilicy & Mayer, 1996). Such an example set presents similar surface-features for different problem types and different surface-features within one problem type.

However, the extent to which learners benefit from the study of worked-out examples also depends on how well the learners explain the rationale of the presented solutions to themselves ("self-explanation effect", Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Renkl, 1997). Most learners do not employ successful strategies such as identifying underlying domain principles and (sub-) goals or anticipating solution steps to a substantial degree (Renkl, 1997). Prompting learners to self-explain during the example study is a method to enhance self-explanation activity and thereby foster learning (e.g., Atkinson, Renkl, & Merrill, 2003). Indeed, sometimes the learner is not able to self-explain correctly. Hence it is reasonable to guide learning further with other instructional methods such as instructional explanations (Renkl, 2002).

However, instructional explanations can also have the effect that learners reduce their self-explanation efforts (Aleven & Koedinger, 2000; Kulhavy, 1977) which reduces learning outcomes. For example, the participants of Schworm and Renkl (2002) learned in a computer-based learning environment for students of Education how to effectively design worked-out examples by studying solved example problems. They were randomly assigned to the four experimental conditions of a 2x2-factorial design: Factor 1: prompting of self-explanations (with and without); Factor 2: instructional explanations (with and without). Results clearly pointed out the advantages of self-explanation prompts. Instructional explanations combined with self-explanation prompts reduced learning outcomes. A further analysis of the learning processes showed that the detrimental effect of instructional explanations was caused by a decrease in self-explanation activity, which in turn had a substantial effect on learning outcome.

In the study conducted by Schworm and Renkl (2002) the learning environment was presented to two different groups of future teachers (from a didactically-oriented program and a subject matter-oriented program) in order to investigate its applicability to different target groups. Results showed that there were differences in the learning outcomes between the two groups. Students of Education from a subject matter-oriented program performed better than Students of Education from a didactically-oriented program.

2. RESEARCH QUESTIONS

The Schworm and Renkl study (2002) resulted in two open questions to which we referred in this study: (1) How can instructional explanations and self-explanation prompts be combined to bring the advantages of both methods to bear? (2) Which factors lead to the differences between future teachers from a didactically-oriented program and future teachers from a subject matter-oriented program, and how is it possible to adjust those differences?

Concerning the first question, the module of the computer-based learning environment used in Schworm and Renkl (2002) was modified to realize a transition from a first learning stage with only instructional explanations to a second learning stage with only self-explanation prompts as one possibility for an effective combination of the two instructional methods. These modifications should help to avoid that learners look up the instructional explanations before they had actively tried to self-explain the examples. Furthermore, the modifications prevent redundancies between self-explanations and instructional explanations in the second learning stage which might produce non-productive load (Sweller et al., 1998).

In order to address the second research question the present study investigated to what extent the differences between the two kinds of students of Education found by Schworm and Renkl (2002) could be replicated and whether they are determined by differences in prior knowledge with regard to the contents of the learning environment.

The following specific research questions were addressed in the present study:

(1) Are there differences between future teachers from a didactically-oriented program and future teachers from a subject matter-oriented program concerning the learning outcomes and the perceived usefulness of the program? If yes, could these differences be attributed to differences in domain-specific knowledge?

(2) Does the transition from instructional explanations to self-explanation prompts have a positive effect on learning outcomes?

(3) Does the availability of instructional explanations reduce self-explanation activity?

(4) Do the different instructional treatments influence the perceived usefulness of the program?

3. METHODS

3.1. Sample and Design

Forty-eight students of Education (mean age: 22.2; 32 female, 16 male) from two different universities took part in the study. Half of the participants were involved in a didactically-oriented program (*n*=24), the other half in a subject matter-oriented program (*n*=24). Furthermore, the participants learned using two versions of a computer-based learning environment which leads to a 2x2-factorial design: Factor 1: instructional treatment (only self-explanation prompts versus transition from instructional explanations to self-explanation prompts), Factor 2: type of program (didactically-oriented versus subject matter-oriented).

3.2. Learning Environment

The learning environment based only on self-explanation prompts was identical to the one used by Schworm and Renkl (2002). The program contained a short introduction about learning from worked-out examples. Then the solved example problems were displayed. They were taken from the domains of geometry and physics. Figure 1 shows a screenshot of the learning environment with a solved example problem about integrated format.

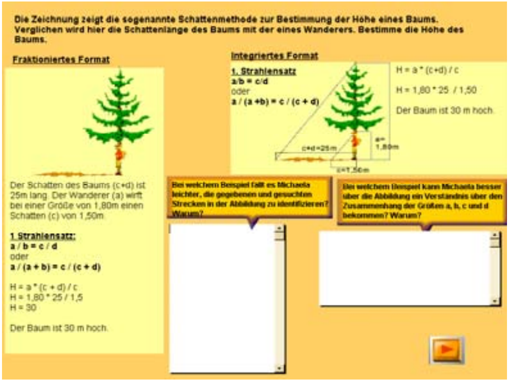

Figure 1. Screenshot of the learning environment for the group with self-explanation prompts only

Figure 1 also illustrates how *self-explanation prompts* were implemented. The prompting of self-explanation asked the learners to write down why one of these two worked-out examples was more favourable. Especially in the beginning of the program the participants were asked to take the perspective of a fictive student previously introduced as Michaela. The first prompting for example contained the following question: "In which example is it easier for Michaela to identify the requested line? Why?" Participants in the group with only self-explanation prompts received 13 prompts, while participants of the combined group received six prompts, which were identical with the last six prompts in the self-explanation only condition. Self-explanations were obligatory, but their extensiveness was self-regulated by the learner.

The *instructional explanations* were answers to the self-explanation prompts. Their demand was obligatory. According to findings from multimedia research (e.g. Mayer & Moreno, 2003) the instructional explanations were presented aurally by clicking a button. To avoid the "fleetingness" of acoustic explanations, a "text"-button enabled the learner to review the explanation in a written format.

3.3. Procedure

The participants began with a pretest of the domain knowledge. The program started with an instructional text about basic principles of worked-out example design. Afterwards, the learners studied several solved example problems dealing with integrated format and structure-emphasizing example sets in the domains of geometry and physics. Subsequently, the participants worked on the post-test (learning outcomes). Finally, they filled out a questionnaire on the perceived usefulness of the learning environment.

3.4. Instruments

A *pretest*, which assessed the domain-specific knowledge that was used in the worked-out examples displayed in the learning program, was assessed by two tasks checking the knowledge of the theorem of intersecting lines, a third task calculating a constant velocity, and a fourth calculating an acceleration.

The *post-test* assessing the learning outcomes had two major parts. First, the participants had to choose which among several given worked-out examples was in an integrated format, or they had to combine four out of eight examples into a structure-emphasizing example set (selection task; maximum: 22 points). The second part comprised a generation demand: The participants had to create a structure-emphasizing example set in an integrated format (maximum: 12 points).

A *questionnaire* included some demographic questions as well as questions concerning the perceived usefulness of the learning environment. The items had to be answered on a Likert scale from 1 to 6. The perceived usefulness scale consists of 19 items (Cronbach's Alpha: .74).

A *coding-system for written self-explanations* was developed. The main categories were as follows:

(1) *Elaborated principle-based explanations.* This category was coded when a statement (a) related design principles and the solved example problem at hand and (b) contained an explanation *why* an integrated format or a structure-emphasizing example set contributes to learning.

(2) "*Simple" principle-based explanations.* The learner referred to aspects of the design principles when inspecting the examples, but did not provide any reasons why the design features are relevant for learning.

(3) *Mathematical content of the solved example problems*.

(4) *Metacognition*.

The written reactions to the self-explanation prompts in the learning program were segmented with the coding categories in mind. The coding categories were distinct and there were no inclusions of segments. Interrater-reliability was reassured (Cohen's κ = .79). The single categories occurred relatively infrequently so that corresponding scores would not have been reliable. We aggregated the codings by adding up the number of elaborations and built a comparable score by dividing the sum of elaborations by the number of prompts (13 and 6, respectively).

4. RESULTS

The pretest correlated significantly with the learning outcomes (r=.31; p<.05). The more the participants knew about the domains used in the program, the better they performed in the post-test on example design. An ANOVA to analyze the group differences in prior knowledge revealed that students of Education from a subject matter-oriented program had a greater domain-specific knowledge than students of Education from a didactically-oriented program (F=14.32, p<.01, η^2=.25). In the following, the pretest was included as covariate.

Table 1 summarizes the descriptive results of the pretest, written self-explanations, perceived usefulness and objective learning outcomes (post-test).

Table 1. Means (standard deviations) of pretest, self-explanations, perceived usefulness, and post-test in the experimental groups.

	Didactically-oriented program - only SE	*Didactically-oriented program- with IE and SE*	*Subject matter-oriented program - only SE*	*Subject matter-oriented program - with IE and SE*
Pretest	2.40 (1.08)	1.57 (0.76)	3.14 (0.77)	2.90 (1.20)
Self-explanations	0.68 (0.20)	0.60 (0.37)	0.82 (0.20)	0.87 (0.38)
Perceived usefulness	2.62 (0.48)	2.97 (0.63)	2.52 (0.35)	2.91 (0.68)
Post-test	17.93 (6.17)	13.24 (6.31)	21.62 (5.38)	23.94 (6.08)

Note: SE = Self-explanation prompts, IE = Instructional Explanations.

In an ANCOVA controlling for the pretest, the instructional treatment showed no effect on the post-test, that is, the learning outcomes ($F(1, 40)=1.20$, $p>.10$). There was no significant influence on the type of Education student ($F<1$). Yet the results yielded a significant interaction between the instructional treatment and the type of Education student ($F(1, 40)=5.61$, $p<.05$, $\eta^2=.12$) (cf. Figure 2).

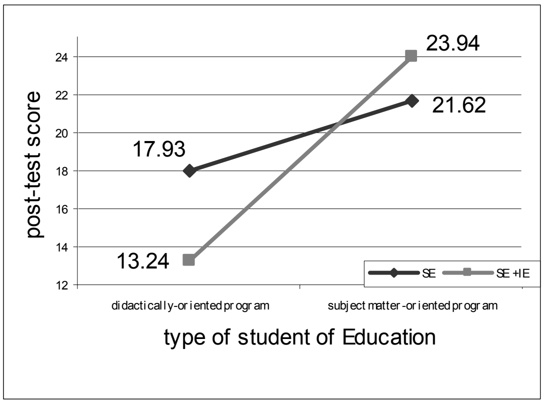

Figure 2. Interaction between experimental condition and type of student of Education with respect to learning outcomes.

Students of Education from a didactically-oriented program performed best in the condition with only self-explanation prompts ($M=17.93$; $SD=5.83$). They showed only suboptimal learning in the program version with instructional explanations and self-explanation prompts ($M=13.42$; $SD=6.31$). Students of Education from a subject matter-oriented program achieved their best results in the latter condition (*M*=23.94; *SD*=6.08) and their performance was only slightly worse in the version with only self-explanation prompts (*M*=21.62; *SD*=6.17).

To prove the influence of the instructional explanations on self-explanation activity, an ANOVA was performed. The results showed no difference between the experimental conditions ($F<1$) and also no interaction between the type of students ($F<1$). However, a difference between the types of students was found ($F(1, 44)=5.61$, $p<.05$, $\eta^2=.11$). According to this, the instructional explanations did not affect the self-explanation activity. But Education students from a didactically-oriented program generated relatively fewer self-explanations overall. The amount of elaborations in the written self-explanations predicted the learning outcomes substantially ($r=.49$; $p<.01$).

The learning conditions differed significantly in their perceived usefulness. The participants ranked the usefulness of the learning environment higher for the program version with instructional explanations than for the one with only self-explanation prompts ($F(1, 44)=5.5$, $p<0.05$, $\eta^2=.11$). There were no differences between the subgroups of Education students ($F<1$) and no interaction effect ($F<1$).

5. DISCUSSION

Overall the transition from instructional explanations to self-explanation prompts is equally effective as giving only self-explanation prompts. Compared to the study conducted by Schworm and Renkl (2002) some good starting points for the application of instructional explanations in a computer-based learning environment have arisen. Instructional explanations do not reduce self-explanation activity and are able to foster learning outcomes, at least when the learners have a high level of domain knowledge. Furthermore, the present study demonstrated the higher perceived usefulness of a learning environment with instructional explanations.

However, not all the learners benefited from the instructional explanations. Students of Education from a didactically-oriented program reached better learning outcomes in the condition with only self-explanation prompts. The interaction effect can partially be explained by the differences in the self-explanation activity between the two types of Education students. Students from a subject matter-oriented program generated more elaborations than students from a didactically-oriented program. Accordingly, their self-explanation activity in the program version with instructional explanations was relatively poor, first because this version presents fewer prompts and secondly because of the few elaborations those participants generated. In the program version with only self-explanation prompts (i.e., many prompts) the low elaboration activity is less detrimental. Due to their high self-explanation activity students of Education from a subject matter-oriented program reached favourable learning outcomes even under the combined condition with less self-explanation prompts, because they *use* the restricted number of prompts *effectively*. For those Education students the elaboration activity is on such a high level that they did not really profit from an increased rate of self-explanation prompts in the program version with only self-explanation prompts. This is consistent with the results of Pirolli and Recker (1994) who came to the conclusion that a high self-explanation activity produces redundancies and consequently the increment of learning becomes smaller.

The difference between the Education students of the two programs is probably also caused by the processing of the instructional explanations. It can be speculated that the students differ in the cognitive load the instructional explanations cause. The worse performance in the pretest of the present study and the worse performance in a creativity test, employed as a pretest in the Schworm and Renkl study (2002) in the group of the Education students from a didactically-oriented program argue for less favourable cognitive prerequisites in this student group. The lower cognitive prerequisites conditions have resulted in a cognitive overload while processing the instructional explanations. If this is true, a reduction of the complexity of the instructional explanations will provide relief.

One conclusion from this study is that help (instructional explanations) and self-explanation prompts should be presented asynchronously. Thus mutual disturbing effects on the instructional treatment can be avoided. Furthermore, it has to be taken into account that there are different kinds of learners whose needs for instructional support through self-explanation prompts vary.

AFFILIATIONS

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