

Help design in a computer-based learning environment teaching argumentation skills through the use of double-content-examples

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Abstract: Learning with self-explaining examples is an effective method in well-structured domains. We analyzed this method in teaching the complex skill of argumentation. In an experiment we compared three conditions ($n = 47$ students of educational sciences) that differed with respect to whether and how the processing of the examples was supported by different help functions. The analysis of the video-based examples was either supported by additional examples displaying the equivalent argumentative structure or by Conceptmaps visualizing the argumentative structure. The control group received no help. We found that examples of argumentation could be successfully employed in order to teach skills of argumentation. Covariance Analysis revealed no main effect of help design on learning outcome. However there was a significant effect of learners' help seeking activities. Learners who used the help facilities more often showed significant higher learning outcomes. Principal based help facilities (concept maps) thereby were most accepted by the learners.

Introduction

Research has shown that learning from worked-out examples (problem, solution-steps and final solution) is of major importance for initial skill acquisition in well-structured domains such as mathematics or physics. However, learners only benefit from this learning mode if they actively explain the examples to themselves (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). The learners can be encouraged to do so by the structure of the examples and by specific self-explanation prompts. Less attention has been paid so far to example-based learning as a learning method for the acquisition of cognitive skills in ill-structured domains. Worked-out examples are usually presented text-based, but examples in ill-structured domains are too difficult to be presented text-based in a sensible way, because thereby relevant context information and proximity to the learners' experiences might get lost. Thus the best way to transmit those complex learning contents may be the use of video- or real-life models displaying people who are, for example, solving a specific problem and/or explicating their cognitive processes. In the current study we used a computer-based learning environment designed to teach basic skills of argumentation. The tool was designed as an example-based learning environment, using video-based examples as expert models. Although originally examples referred to well-structured written problem statements and corresponding solution steps, the modelling of an ill-structured cognitive skill can also be understood as an example. In this context self-explanations could be regarded as an activity to symbolically code the key behaviours of a model's performance.

Results of previous studies showed that self-explanation prompts foster learning of ill-structured cognitive skills (here: argumentation skills) by video-based examples (Schworm & Renkl, 2007). However, learning results were far from optimal. As a consequence help functions have been implemented in the learning environment supporting learners when analysing the argumentation examples. Different types of help were employed in order to foster active processing. We tested whether and how the instructional approach of additional examples displaying the equivalent argumentative structure or concept-maps visualizing the argumentative structure can be employed in order to foster argumentation knowledge.

Self-Explanations and Instructional Explanations in Learning from Worked-Out Examples

Worked-out examples consist of a problem formulation, solution steps, and the final solution itself. They enable the learner to study an expert's solution of a particular problem with an algorithmic solution. Such examples are typically employed in domains such as mathematics or physics. Research has shown that learning from such examples is of major importance for initial skill acquisition of cognitive skills in these domains (e.g., Atkinson, Derry, Renkl, & Wortham, 2000; Renkl, 2005).

However, learners only benefit from this learning mode if they actively explain the examples to themselves. This phenomenon is called self-explanation effect (Chi, et al, 1989; Renkl, 1997). Unfortunately most learners self-explain in a very superficial way or even not at all (Renkl, 1997). A promising instructional approach towards this problem is the implementation of prompts. Prompts are questions or elicitations which aim to induce deeper level learning activities. More specifically, they elicit learning strategies such as self-explanation activities that the learners are capable of but do not show unpremeditated (cf. King, 1996; Pressley et al., 1992). Several studies provided evidence that prompting self-explanations foster learning from examples (Atkinson, Renkl, & Merrill, 2003; Wong, Lawson, & Keeves, 2002). However, solely relying on self-explanations may as well lead to some problems. Sometimes the learner is not able to self-explain or the given self-explanations are incorrect (Renkl, 1997). Renkl (2002) therefore developed a set of instructional principles to support the spontaneous self-explanation activity by providing instructional explanations (SEASITE principles; Self-Explanation Activity Supplemented by InsTructional Explanations). Two central principles were (1) the priority of self-explanation activities (instructional explanations should just be used as type of support) and (2) the provision of instructional explanations on learner demand. In the study of Renkl (2002), the SEASITE principles were implemented in a computer-based environment. It could be shown that such instructional explanations heightened the average learning outcomes.

However, Schworm and Renkl (2006) provided some evidence that the availability of on-demand help sometimes interferes with productive learning processes. In a computer-based learning environment, designed to help student teachers learn how to design and combine examples when preparing a mathematical lesson, the impact of prompts for self-explanations and the provision of instructional explanations was examined in a 2x2 factorial design. The prompts asked learners to enter their self-explanations. The learners were not able to continue with the program without providing some amount of elaboration. The instructional explanations were presented at the students' request. After they finished their work with the program, the students completed a post-test. Of the four conditions, the self-explanation only group (who were prompted to self-explain but could not request instructional explanations) did best with respect both to the amount of the elaboration activity and their learning outcomes. When prompts for self-explanations were combined with instructional explanations provided by the system, learners reduced their self-explanation activity and their learning outcomes diminished. A possible explanation for this effect may be learners missing awareness of their need for help. Similar to their self-explanation activities learners do not use help facilities effectively, most of the time they do use it superficially or even not at all (Aleven, Stahl, Schworm, Fischer & Wallace, 2003).

Different Types of Examples Providing Solutions

Besides worked-out examples from algorithmic contents domains, there are other types of examples providing problem solutions. Examples can differ in two respects: (a) the availability of discrete solution steps and (b) the content levels involved in the examples.

Classical worked-out examples provide solution steps that lead to the final solution and they have only one content level. However, there are cases where no algorithmic solution can be provided, for example, in the case of a good written article. Here, an example only includes (a) the problem formulation, that is, the topic of the article and the expectations with respect to the structure of an article, and (b) the final solution or product. At the same time, there are necessarily two content levels that have to be processed by a learner who tries to profit from elaborating an article as a good example: (a) the topic of the article and (b) the features that make the article a well-written one (e.g. its logical structure). The learner has to integrate information from both content levels. For example, the logical structure of an article can not be analyzed and later be transferred to one's own writing processes without understanding what the article is written about. In the case of learning to write, the main focus of learning is on how to structure an article. This content domain is called *learning domain*. The domain that is used to exemplify the features of a good article is called *exemplifying domain*. The contents of the situation description do not constitute a learning domain in itself, with principles to be understood. In the case of examples from non-algorithmic domains, a complex part of a domain is typically used to exemplify a problem solution. The basic principles of the exemplifying domain have to be understood by the learners in order to be able to see how the principles of the learning domain are instantiated in the exemplifying domain. If the learners do not understand the exemplifying domain, they certainly have difficulties in recognizing how the principles of the learning domain are realized (cf. Schworm & Renkl, 2007).

If the examples are taken from domains where no discrete algorithmic solutions can be provided and two domains (i.e., learning domain and exemplifying domain) have to be considered the examples are called *double-content examples* (Schworm & Renkl, 2007). Double-content examples that have already been investigated were from learning domains such as the design of effective learning materials for high-school students (Schworm & Renkl, 2006; exemplifying domain: among others, intersection theorem) or effective interdisciplinary cooperation (Rummel & Spada, 2005; Rummel, Spada, & Hauser, 2006).

Learning with Self-Explaining Double-Content Examples

In their study Schworm and Renkl (2006) were able to show that actively self-explaining double-content-examples improves learning. There was another considerable finding related to the types of student teachers for mathematics and physics that participated in the experiment: student teachers from the subject-matter-oriented program clearly outperformed the student teachers from the instructionally-oriented program with respect to their self-explanation activity and their learning outcomes on example-design principles. It was assumed that the student teachers from the instructionally-oriented program probably had difficulties in understanding the exemplifying domains which hindered to profoundly explain the learning materials to themselves. Unfortunately, there was no direct measure of the mathematics and physics knowledge available in this study.

In a follow-up study by Hilbert, Schworm, and Renkl (2004), using the same learning materials, the superiority of the student teachers from the subject-matter-oriented program with respect to self-explanations and to learning outcomes could be replicated, and it could be shown that the two types of student teachers differed in their mathematics and physics background knowledge (i.e. in their exemplifying domain knowledge) which was, in turn, significantly related to the learning outcomes on example-design features (i.e. the learning domain).

An aspect which had not been analyzed so far was the content of the self-explanation prompts. In the studies mentioned above self-explanation prompts always contained questions concerning the learning-domain. However, research has shown that the understanding of the exemplifying domain should be taken into consideration. Decker and colleagues (Decker, 1980; 1982; Hogan, Hakel & Decker, 1986) investigated learning from examples of assertive behavior. To foster symbolic coding in behavior modeling training he presented his participants learning codes while they were observing the model's performance. Learning codes contain the explanatory information about the relevant modeled behaviors. Decker (1980, 1984) compared descriptive learning codes with rule-based learning codes. Descriptive learning codes described the model's behavior verbally (i.e. they referred to the exemplifying domain). Rule-based learning codes described the principles underlying the model's performance (i.e. they referred to the learning domain). Results showed that descriptive coding produced more accurate reproduction of the observed behavior. Rule-based codes provided to the learners fostered generalization more than descriptive codes. Decker (1980) compared as well two different sources of rule-based learning codes. In the self-explanation condition the trainees were told that there were several rules underlying the modeled behavior, and between the first and the second viewing they should write down what they thought those rules had been. In the instructional explanation condition the learning codes were presented as they were in the first experiment. Results showed that trainee-generated learning codes (i.e. self-explanations) enhanced generalization and reduced reproduction decay. Schworm and Renkl (2007) analyzed to what extent those results hold true to learning from double-content examples in the domain of argumentation. They implemented a one-factorial design with four instructional conditions: (a) no self-explanation prompts; (b) eight exemplifying-domain self-explanation prompts; (c) eight learning-domain self-explanations prompts; (d) mixed prompts, that is, four exemplifying-domain self-explanation prompts and four learning-domain self-explanations prompts. Argumentation knowledge and skills were assessed. They found that examples of argumentation could be successfully employed in order to teach declarative knowledge about argumentation. However, when the skill of argumentation was to be fostered prompts that direct the learners' attention to the principles of argumentation (i.e. the learning domain) should be employed.

Summed up, the results reported above, show convincing evidence that learning from double-content examples is a powerful instructional method in various domains. Learning thereby can be fostered by using self-explanation prompts emphasizing the content of the learning domain. However, learning argumentation by self-explaining examples is a challenging task and learning outcomes have been far from optimal (Schworm & Renkl, 2007). Thus the implementation of instructional help fostering learning by double-content examples is an interesting point of further research.

Research Questions

Based on the results of Schworm and Renkl (2006, 2007) the learning environment teaching argumentative skills was enriched by a help system. The aim of the help system was to enhance learners' understanding of the content of the learning domain.

In this experiment, we used a computer-based learning environment that was developed to teach the basic skills of argumentation as stated in the work of Kuhn (1991). Kuhn investigated, for example, to which extent people are able to separate theory from supporting evidence or bracket their own theory, taking the perspective of a potential opponent. Her results revealed that people have large difficulties in generating alternative theories or counterarguments against their own theory, although the participants were supposed to have at least basic knowledge in the chosen domains. Thus, the goal of the learning environment was to teach (a) to make the difference between theory and evidence, (b) to consider the possibility of different perspectives, and (c) to recognize the fallibility of their own opinion. Those skills of argumentation were taught by video-

based examples which displayed argumentative dialogues in two different exemplifying domains. The use of multiple examples is a relevant aspect of example-based learning (Atkinson, Derry, Renkl, & Wortham, 2000; Renkl, 2005). However, the duration of the single example dialogues (six minutes each, played in four segments, each segment presented twice) makes the direct comparison of example features which is necessary for generalization quite difficult. Therefore the idea of multiple examples was integrated in the help system. One of the help systems contained additional examples with the equivalent argumentative structure but of different exemplifying domains. The help system to be compared contained instructional explanation displaying concept maps which presented the relevant structure of the argumentative dialogue. Even though giving instructional explanations implies the risk of reducing learners' activity, they may reduce cognitive load by focusing the learners' attention on the relevant aspects of the learning domain. On the other hand, additional examples may lead to higher learning activities, comparing the presented sequences. However, they may as well overwhelm the learners' by confronting them with additional exemplifying domains.

Specifically, the following research questions are addressed:

- (1) Does additional instructional help foster argumentation knowledge compared to self-explanation prompts only?
- (2) Do the different kinds of instructional help have different effects on the acquisition of argumentation knowledge?
- (3) Do the different kinds of instructional help have different effects on the acceptance of the learning environment?

Methods

Sample and Design

We implemented a one-factorial design with three instructional conditions: (a) Feedback on the correctness of the multiple choice question, but no help function; (b) Feedback on the correctness of the multiple choice question and example-based help function (multiple example condition) (c) Feedback on the correctness of the multiple choice question and principle-based help function (instructional explanation condition).

Fifty-one student teachers volunteered to take part in this study (mean age: 24.06 years; 34 female and 13 male participants; most of the students studied educational science (53%); the mean study time was about 1 semester). The study lasted about three hours. They were randomly assigned to one of the three experimental conditions ($n = 17$ in each group). Four participants had to be excluded from the sample, because they cancelled participation without doing the posttest. All participants of the experimental groups received eight self-explanation prompts. In the first experimental group a help system was implemented displaying the equivalent argumentative structure of the video-based example using a different exemplifying domain. In the second experimental group a help system was implemented displaying the argumentative structure of the video-based example visualized by a concept-map. The participants of the control group had the opportunity to write down their self-explanations; they did not, however, get any help by the system.

Procedure and Learning Environment

Procedure and learning environment was equivalent to those used by Schworm and Renkl (2007). The participants worked in sessions of approximately three hours. First, several pretests were provided. A paper-pencil test with *multiple-choice items on prior knowledge in the content areas of the video-based examples* (i.e., stem-cell research and achievement differences of girls and boys in mathematics and natural sciences) was provided. This allows for testing possible groups differences in exemplifying domain knowledge. Afterwards two computer-based *tests on argumentation knowledge* (i.e., declarative knowledge about argumentation and argumentation skills) were administered.

In the actual learning phase explanatory information about the argumentative model of Kuhn (1991) was given - integrated in the computer-based learning environment. The participants received information about the relevance of genuine evidence to support their theory and about the advantages of accounting for possible alternative theories and counterarguments. This theoretical information was supplemented by an example. Second, the video-based examples were introduced. In a cover story two young teachers were introduced who participated in a workshop. The video-based examples showed two conversations in the run-up of the workshop. The dialogue content was taken from two (exemplifying) domains, (a) stem-cell research, and (b) achievement differences of girls and boys in mathematics and natural sciences.

The dialogue was presented in four sequences. Here the experimental manipulation took place. After each sequence a multiple choice question was presented which asked for the learning content of the forgoing dialogue. All participants received a feedback about the correctness of their answer respectively which one would have been the correct one. If they chose the wrong answer in the experimental conditions help was offered system-initiated. In the group with the example-based help an argumentative dialogue was displayed showing the equivalent argumentative element (e.g. rebuttal of a counterargument) within another exemplifying domain (e.g. the advantages of problem-based learning). In the group with principle-based help a concept map

was displayed showing the structure of the argumentative elements of the dialogue content with additional instructional explanations (e.g. explaining why the statement of the dialogue was a successful counterargument against the original theory).

Instruments

Pretests

The first pretest tapped on the *knowledge about the content areas of the video-based examples (exemplifying domains)*. It contained 28 multiple-choice items about the content of the exemplifying domains (14 about the exemplifying domains of the original video-based examples; 14 about the examples of the help systems, which were only applied to the example-based help condition). For each item one point was awarded for the correct choice.

The learning environment intended to teach knowledge about Kuhn's argumentation model (Kuhn, 1991) as well as corresponding skills on argumentation. Hence the *pretest on argumentation knowledge (learning domain)* contained two separate subtests. The *pretest on declarative knowledge about argumentation* contained two questions in an open format: (a) "What is good argumentation?" (b) "What are the elements of good argumentation?" The two questions were presented at once on the screen. The time to answer them was restricted to 10 minutes. Afterwards the program continued automatically. The answers of the questions were categorized according to the goals of the learning environment. A maximum of three points for the first question was awarded if the participants (a) mentioned the difference of theory and evidence, (b) stated the possibility of different perspectives, and (c) recognized the fallibility of their own opinion. A maximum of six points was assigned for the second question if the participant enumerated the following elements: theory, evidence, alternative theory, rebuttal of the alternative theory, counterargument, and rebuttal of the counterargument. For coding, the notions themselves were not of importance. If the participant had described the content of the concepts in any way, the point was awarded. A maximum of nine points could be achieved.

Finally there was a *pretest on argumentation skills* that contained six questions in an open format. The questions are taken from Kuhn's interview (Kuhn, 1991), translated into German and slightly adapted according to the current context: (a) What do you think is the cause of school failure? (b) How would you prove that this is the cause? (c) What might somebody else, who does not agree with you, think is the cause of school-failure? (d) What could you tell her/him to show s/he is wrong? (e) What might somebody else say to show that your opinion about the cause of school failure is wrong? (f) What could you tell her/him to show s/he is wrong? Each question was presented separately. The time to answer each question was restricted to 5 minutes. Afterwards the program continued automatically. If the participants did not need the full amount of time they were allowed to continue self-contained. The answers were coded according to the coding-system based on the work of Kuhn (1991) which has already been used in the study of Schworm and Renkl (2007) (cf. Schworm and Renkl, 2007 for a description of the coding scheme). For a score, the ratings were aggregated. A totally correct solution was awarded with 9 points. This maximum of points included (a) a theory and its supporting genuine evidence, (b) a correct alternative theory and its rebuttal, and (c) a successful counterargument and its rebuttal.

Post-tests

The post-test on *declarative knowledge about argumentation* was identical to the corresponding pretest. The *post-test on argumentative skills* contained – just as the corresponding pretest - six open questions. The topic was the performance of German students in international comparative studies on school achievement (TIMSS, PISA). The questions' contents were equivalent to the questions of the corresponding pretest. The scoring procedure was also identical.

Part of the materials was coded by two rates: graduate students doing their thesis in the research project. They were trained in the run-up of the study using equivalent data gained by testing the materials. In the actual study a set of approximately 20 pretests or post-tests on argumentation was randomly selected. These tests were independently categorized by the two raters (Cohen's kappa = .89). As the objectivity of coding proved to be good, the remaining tests were coded by one coder who was blind to the experimental condition.

Questionnaire

A questionnaire assessed some demographic questions as well as the acceptance of the learning environment (e.g. "The content of the program has been easy to understand"). The nine acceptance items had to be answered on a Likert scale from 1 to 6. We obtained a Cronbach's Alpha of .71. Additionally the acceptance of the help systems was assessed by 6 Items. We obtained a Cronbach's Alpha of .89.

Written self-explanations

While working with the learning environment the learners were prompted eight times to write down their self-explanations. The written self-explanations were analyzed using a specifically developed coding system (cf. Schworm and Renkl, 2007 for a more detailed description of the coding scheme).

In this study we concentrated on two main categories:

1. Exemplifying-domain self-explanations referred to the contents of the dialogue
2. Learning-domain self-explanations referred to the argumentative structure of the dialogue

The self-explanation activities of five participants were randomly selected and the coding system was independently applied by the same two raters who coded the pretests and post-tests. Inter-rater-agreement was good (Cohen's $\kappa = .79$).

Results

An alpha level of .05 was used for all statistical tests. When performing contrasts that corresponded to our hypotheses by t-tests, we used one-tailed testing; otherwise we employed two-tailed tests. As an effect size measure, we used (partial) η^2 – qualifying values $< .06$ as weak effect, values in the range between .06 and .13 as medium effect, and values $> .13$ as large effect (cf. Cohen, 1988; pp. 285-287).

Pre-analysis

The instructional groups did differ in the knowledge about the content areas of the video-based examples ($F = 6.77, p < .01, \eta^2 = .21$). However, knowledge about the exemplifying domain did not correlate with any post-test measure (knowledge about argumentation, $r = .09, p > .10$; argumentative skills, $r = .01, p > .10$).

There was a difference in time-on-task between groups, $F = 5.16, p < .01, \eta^2 = .19$. This effect got significant due to the fact that the example-based help group needed more learning time than the principle-based help group and the control group. There was a positive correlation between time on task and post-test on knowledge about argumentation, $r = .43, p < .01$ (argumentative skills, $r = .01, p > .10$). Time on task was therefore integrated as a covariate in further analyzes.

In the pretest on declarative knowledge about argumentation, in which a maximum of nine points could be achieved, the learners reached an average score of about one point ($M = 1.51, SD = 1.21$). There were no differences between the experimental conditions ($F < 1$). In the pretest on argumentative skills, in which also a maximum of nine points could be achieved, the average performance was as well rather low ($M = 2.30, SD = 1.71$). Again, there were no differences between the experimental conditions, $F < 1$.

Effects of help use on learning outcome

To evaluate the usefulness of the help system it is essential that it has been used by the learner. Learners' need for help therefore has been integrated in the analysis as covariate. So has been done with learners' score of self-explanation activity which highly correlated with learning outcomes (knowledge about argumentation, $r = .55, p < .01$; argumentative skills, $r = .35, p < .05$).

Declarative knowledge on argumentation

An ANCOVA was calculated, controlling help use, self-explanation quality and time on task. We did not obtain a significant main effect of the experimental treatment, $F < 1$. There was no significant effect of time on task ($F(4,43) = 3.40, p > .05, \eta^2 = .08$). There was as well no effect of help use $F < 1$. However, there was a significant effect of learners' self-explanation quality ($F(4,43) = 9.54, p < .01, \eta^2 = .19$) of a strong practical significance.

Argumentative skills

An ANCOVA was calculated, controlling help use, self-explanation quality and time on task. We did not obtain a significant main effect of the experimental treatment, $F < 1$. There was no significant effect of time on task ($F(4,43) = 2.33, p > .10, \eta^2 = .06$). However, there was a significant effect of help use on learning outcome ($F(4,43) = 10.28, p < .01, \eta^2 = .20$). There was as well a significant effect of learners' self-explanation quality ($F(4,43) = 12.53, p < .01, \eta^2 = .24$). Both effects were of a large practical significance.

Effects of different kinds of help on the acceptance of the learning environment

When looking at the single experimental conditions where a system-based help function was implemented, we found a significant difference in the acceptance of the help system by the learners ($t(30) = 2.41, p < .05$), with the principle-based help ($M = 3.82, SD = .89$) being more appreciated than the example-based one ($M = 3.17, SD = .61$). However, groups did not differ in their over all acceptance of the learning environment ($F < 1$).

Discussion

The present findings can be summarized as follows. Video-based double-content examples can effectively be implemented in a computer-based learning environment in order to foster declarative knowledge about argumentation as well as argumentative skills. So far learning results have been far from optimal. The complexity of the learning domain makes additional instructional support unavoidable. Results showed that the use of the help provided by the system fostered learning outcome. This holds even truer, taking into account that the systems' help was initiated by an error of the learner. Thus, it was the weak learners who benefited most. On the other hand this might as well be one of the weaknesses of the study. Strong learners who already were able to draw the relevant conclusions out of the video-based examples were not offered the opportunity to benefit from additional help.

This point of view is undermined by the relevance of learners' self-explanations for declarative knowledge on argumentation as well as argumentative skills. Help use did not correlate with learners' self-explanation activity ($r = -.11, p > .10$). Successful self-explainers probably had no need for help.

Analyzing the different types of help there seems to be no difference between example-based help, principle-based help and plain feedback about the correctness of the task. However, correlation analysis reveals that the positive effect of help use on learning outcome is based on the significant positive correlation of the use of principle-based help and argumentative skills as assessed by the post-test ($r = .64, p < .01$). In the other experimental conditions there was no significant positive relation between those variables. The positive role of the principle-based help is as well underlined by its higher acceptance of the learners.

Summed up, the implementation of the help system can be judged as successful. However, several open questions remain. The implementation of the help-system did not lead to the expected differences in learning outcome compared to the feedback-only condition. Probably the multiple-choice question offered – especially if not answered correctly – the opportunity to get aware of ones misunderstanding. Being given the correct solution in some cases might have been already enough “help” to foster learning. Even if the help was given system-initiated it is the responsibility of the learner to actively process the given help. Regarding time on task, there were no differences between the principle-based help group and the control group. Assuming that the processing of the help should require some time, it seems that the systems help was not elaborated very deeply. Higher time on task in the example-based help group might result due to the plain duration of the video. This does not automatically include active processing. A thinking-aloud study probably would be helpful analyzing the learning processes while elaborating the help presented.

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