Worked-out examples: instructional explanations support learning by self-explanations

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Abstract

Learning from worked-out examples is very effective for initial skill acquisition, at least when learners actively explain the solution steps in the examples to themselves. However, learning solely on the basis of self-explanations is connected with several restrictions, even when effective self-explaining is trained or elicited. Therefore, a coherent set of principles for integrating instructional explanations into learning via self-explanations was developed, implemented, and tested. An experiment with a control group (without instructional explanations; 20 student teachers) and an experimental group (with instructional explanations; n=28) was conducted. The results showed that the instructional explanations had a positive effect on learning, at least under certain conditions. In addition, deficits in the use of the instructional explanations were identified and possible ways to improve the effectiveness of the instructional explanations were proposed. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Worked-out examples consist of a problem formulation, solution steps, and the final solution itself. Research has shown that learning from such examples is of major importance for the initial acquisition of cognitive skills in well-structured domains such as mathematics, physics, and programming (for an overview see Reimann, 1997 VanLehn, 1996). In addition, this learning mode is preferred by novices, and they
are correct in this notion: it is indeed quite an effective way of learning. Zhu and Simon (1987) found that their carefully designed and sequenced mathematical examples were sufficient to induce skill acquisition and abstract problem representations without providing explicit instruction. Studies performed by Sweller and his colleagues (e.g. Sweller & Cooper, 1985; for an overview see Sweller, van Merrienboer, & Paas, 1998) showed that learning from worked-out examples can be more effective than learning by problem solving.

Although worked-out examples have significant advantages, their employment as a learning methodology does not, of course, guarantee effective learning. First, how the examples are structured is important (cf. Atkinson, Derry, Renkl, & Wortham, 2000). Second, the extent to which learners profit from the study of examples depends heavily on how well they explain the solutions of the examples to themselves (Chi, 2000; Chi, Bassok, Lewis, Reimann, & Glaser, 1989). The second aspect is the focus of this study. More specifically, this article investigates an instrument to support the learners’ self-explanation activities by the provision of instructional explanations.

Before the corresponding study is described, the most important research findings on the significance of self-explanations and on possible ways of fostering them are reported. This is followed by the development of a set of principles for the design of a learning environment in which instructional explanations supplement self-explanations.

2. The significance of self-explanations in learning from worked-out examples

Chi et al. (1989) showed that the extent to which learners profited from the study of worked-out examples (content domain: physics/mechanics) depended on how well they explained the rationale of the presented solutions to themselves. This was called the ‘self-explanation effect’. Specifically, the successful learners, as compared to those who were less successful, could be characterized as follows: (1) the successful learners devoted more time to the study of the worked-out examples; (2) they elaborated on the application conditions and goals of operators more frequently; (3) they related operators to domain principles (principle-based explanations) more regularly; and (4) they less frequently had illusions of understanding. Pirolli and Recker (1994) replicated these results using worked-out examples from the domain of programming.

In the study of Chi et al. (1989), the successful and the unsuccessful learners differed with respect to both quantitative (learning time) and qualitative (quality of the self-explanations) aspects. For this reason, Renkl (1997a) fixed the learning time for each individual in his study so that the true impact of qualitative differences in self-explanation activities could be isolated. It was found that the quality of self-explanations was significantly related to learning outcomes even when learning time was kept constant. Specifically, the successful and the unsuccessful learners differed with respect to the following main points. (1) The successful learners frequently assigned meaning to operators by identifying the underlying domain principle (principle-based explanations). (2) They frequently assigned meaning to operators by
identifying the (sub-)goals achieved by those operators (explication of goal–operator combinations). (3) They tended to anticipate the next solution step instead of looking it up (anticipative reasoning). (4) The less successful learners explicated a greater number of comprehension problems, that is, they had metacognitive awareness of their own learning difficulties (metacognitive monitoring). This latter finding diverged from the results of Chi et al. (1989). It is most likely that in contrast to the learners in the investigation conducted by Chi et al., the learners in Renkl’s study could not resolve their comprehension impasses as informal observations indicated very often. The latter learners would have needed external support.

In addition, Renkl (1997a) found that the successful learners often did not show all of the types of self-explanations that were positively related to learning outcomes. A cluster analysis revealed that there were two types of successful learners: principle-based explainers and anticipative reasoners. Principle-based explainers concentrated their self-explanation efforts on the assignment of meaning to operators, both by principle-based explanations and by explicating goal–operator combinations. They did not frequently anticipate solution steps. This, however, was extensively done by the anticipative reasoners, who refrained from many principle-based explanations and from the repeated explication of goal–operator combinations. In summary, there were two ways utilized in successful learning.

Besides these two types of successful learners, there were two unsuccessful groups: passive and superficial explainers (for details see Renkl, 1997a). The passive explainers’ poor learning outcomes could be attributed to the very low level of self-explanation activity. Superficial explainers, on the other hand, assigned relatively little time to each worked-out example. Although they were moderately successful, they explicated few comprehension problems. With respect to their deficient metacognitive awareness of their learning difficulties, the superficial explainers resembled the less successful learners described by Chi et al. (1989).

It is important to note that most learners belonged to the unsuccessful groups. Given these deficits, it is important to search for instructional interventions in order to foster self-explanation activities and, as a consequence, learning results. Several researchers have already published reports about experiments in which self-explanations were successfully fostered. These studies did not, however, concentrate on (pure) learning from worked-out examples (Bielaczyc, Pirolli, & Brown, 1995: text and examples; Chi, DeLeeuw, Chiu, & LaVancher, 1994: text; Neuman & Schwarz, 1998: problem solving). One exception is the work of Conati and VanLehn (Conati, 1999 Conati & VanLehn, 1999) who supported learning from worked-out examples through a fairly sophisticated computer-based intelligent tutor. The tutor contained templates which were to be filled in by browser items (physics rules or sub-goals in a solution plan) as ‘building blocks’ of self-explanations. In addition, the tutorial component gave hints as to which aspects needed further self-explanations. Contrary to expectation, however, this tool did not foster learning gains in a first empirical evaluation study (except that some sub-groups could be identified post hoc as profiting from the tool, Conati, 1999).

In the following section, two experiments that investigated effective ways to
enhance self-explanations during example study, and consequently learning outcomes, are discussed.

3. Fostering self-explanations and learning outcomes

The findings of Renkl (1997a) suggest that there are two ways of learning successfully from worked-out examples: (a) via the assignment of meaning to operators by principle-based explanations and by the explication of goal-operator combinations; and (b) via the anticipation of solution steps. In the following two studies, these two successful ways of learning were analysed experimentally. The first study addressing the assignment of meaning to operators by principle-based explanations and by the explication of goal–operator combinations and the second study focussing on the anticipation of solution steps.

Renkl, Stark, Gruber, and Mandl (1998) addressed the finding of Renkl (1997a) that some effective learners frequently assign meaning to operators, both by principle-based explanations and by explicating goal–operator combinations. They tested experimentally the extent to which an elicitation procedure for fostering the explication of goal–operator combinations and principle-based explanations enhances the acquisition of skills in the computation of compound interest and real interest. (In addition, the effects of example variability were investigated; this is, however, not relevant in this context.) In an experimental group, the learners were informed about the importance of self-explanations. Then a model depicting how to self-explain was presented to the participants in the experimental group. Subsequently, they self-explained a worked-out example, and were coached by the experimenter. As a final step, the participants independently learned from worked-out examples, just as the members of the control group had done. The control group merely received a thinking-aloud training instead of a self-explanation training. The learning outcomes were measured with near-transfer problems (in comparison to the examples presented for learning: same underlying structure, different surface features) and far-transfer problems (changed structure and changed surface features).

The following main findings were obtained. The elicitation procedure had a very strong effect on self-explanation activities (Renkl, Stark, Gruber, & Mandl, in press). As a consequence, learning outcomes were enhanced with respect to near-transfer and far-transfer performance. In the case of near-transfer, the positive effect of the elicitation procedure was primarily caused by the learners with low prior topic knowledge (aptitude-treatment interaction). Only these persons profited substantially from this instructional support (Renkl et al., 1998).

Despite the encouraging results of this experiment, the effects of the elicitation procedure were not completely satisfying. Qualitative analyses of the learners’ verbal protocols revealed that there were three major problems. First, although the elicitation procedure was successful in increasing the number of self-explanation elements, the quality and correctness of the self-explanations were in many cases far from being optimal. Second, some learners processed the examples rather passively and superficially, although they were supported by the elicitation procedure. Thus, in some
cases, the instructional intervention was not successful. Third, some learners had substantial comprehension problems, irrespective of whether they were supported by the elicitation procedure or not. Hence, the difficulties of weak learners already found in Renkl (1997a) could be reduced, but not eliminated. These problems demonstrate the necessity of searching for further instructional methods in the effort to optimise learning from worked-out examples.

In his dissertation project, Stark (1999) further researched the finding from Renkl (1997a) that one group of successful learners had concentrated their efforts on the anticipation of solution steps. He investigated the extent to which the insertion of ‘blanks’ that, in a certain sense, forced the learners to determine (anticipate) the next solution step on their own fostered learning. It was assumed that by doing so the learners process the examples more actively (see also Reimann’s assumptions on expectation-driven example processing; Reimann, 1997; Reimann, Schult, & Wichmann, 1993). In addition, elements of active problem solving were integrated into learning from examples by requiring the learners to anticipate (Renkl, 1997a; Stark, 1999). Hence, the learners could gain metacognitive knowledge about the extent to which they were already able to solve problems. This effect should reduce the frequently found ‘illusions of understanding’ (cf. Chi et al., 1989; Pirolli & Recker, 1994). In addition, the learners began to do what they were ultimately expected to do, namely, to solve problems (i.e. to generate solution steps).

In his experiment, Stark (1999) employed the worked-out examples, instruments, and materials of Renkl (1997a) in slightly modified forms. The examples were presented successively, that is, in a step-by-step procedure. Half of the participants studied incomplete examples (experimental group), the other half learned from complete examples (control group). In the experimental group, parts of the example solutions presented were replaced by ‘question marks’. The learners were to name what was missing. After doing so or at least after making the attempt, the complete solution step was presented so that there was feedback on the correctness of the learners’ anticipations.

It was found that the employment of incomplete examples fostered performance on problems with the same structure but with changed surface features (defined as near-transfer), and on problems with changed structure but similar surface features (medium-transfer). In addition, incomplete examples promoted the performance on a construction task in which the learners were required to design a probability problem with a certain underlying structure. The learners who studied incomplete examples also performed better on far-transfer problems (changed structure and surface features). This difference did not, however, reach the level of statistical significance. Aptitude-treatment interactions were not found in this study. This means that, in contrast to the results of Renkl et al. (1998), the effects of incomplete examples were independent of the learners’ cognitive prerequisites.

Protocol analyses of the self-explanations in both groups showed that incomplete examples significantly fostered the quality of self-explanations. Nevertheless, the self-explanations of the learners studying incomplete examples were far from being optimal. The problems of unresolved comprehension impasses and of the occurrence of incorrect self-explanations were found again, just as in the studies described
above. Hence, much could and should be done to improve the quality and correctness of the learners’ self-explanations further.

4. Self-explanation activity supplemented by instructional explanations: the SEASITE principles

The instructional means that were chosen in order to foster learning from worked-out examples were successful with respect to the enhancement of learning outcomes. However, even when instructional interventions were employed, the quality of self-explanations was far from satisfying. These limitations are most likely inherent in learning situations in which learners are completely dependent on their self-explanation activities. In order to improve learning from worked-out examples further, it is logical to look for fruitful possibilities that combine self-explanation activities with explanations from others such as tutors or teachers (in the following shortly: instructional explanations; see also Renkl, 1999).

So far we have focussed on self-explanations and attempts to improve them. Explanations from more knowledgeable persons (e.g. teachers or tutors) were not considered, although they are dominant in traditional forms of instruction. The major reason for this was that the results of studies on learning from examples indicate that instructional explanations are very often ineffective and inferior to self-explanations (e.g. Brown & Kane, 1988 Chi, 1996 Stark, in press). Hence, it is not a trivial task to provide effective instructional explanations in this context. A careful analysis of the (dis-) advantages of instructional explanations is necessary.

4.1. Comparison of self-explanations and instructional explanations

Instructional explanations as compared to self-explanations have at least three main disadvantages which help to explain these findings (see Fig. 1).

1. Non-adaptation to the learner’s prior knowledge. Quite often instructional explanations are not adapted to the prior knowledge of the individual learner, the result

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<tr>
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<th>Self-explanations</th>
<th>Instructional explanations</th>
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<tr>
<td>Adaptation to prior knowledge</td>
<td>YES</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Timing</td>
<td>FAVOURABLE</td>
<td>Uncertain</td>
</tr>
<tr>
<td>Generation effect</td>
<td>YES</td>
<td>No</td>
</tr>
<tr>
<td>Correctness</td>
<td>Uncertain</td>
<td>GIVEN</td>
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<tr>
<td>Solving comprehension problems</td>
<td>Difficult</td>
<td>MEDIUM</td>
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<tr>
<td>Comprehension monitoring</td>
<td>Unfavourable</td>
<td>MEDIUM</td>
</tr>
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Note. Capital letters: More favourable features of self-explanations or instructional explanations respectively.

Fig. 1. Advantages and disadvantages of self-explanations and instructional explanations.
being that the learner cannot understand them. Self-explanations, in contrast, are constructed out of the learner’s prior knowledge; hence, they are automatically adapted.

2. **Timing.** Some research findings suggest that a learner profits from instructional explanations only when s/he integrates them into an ongoing activity such as problem solving or reasoning about something (cf. Neber, 1995 Webb, 1992). Whereas self-explanations are an integral part of ongoing learner activities, it is no small task to assure appropriate timing for instructional explanations.

3. **Generation effect.** Many studies on human memory have shown that self-generated information is better remembered than presented information. Thus, self-explanations should be better retained than instructional explanations (see also Lovett, 1992).

The findings of the studies reported above show, however, that relying only on self-explanations also has serious problems in three respects (see Fig. 1).

1. **Correctness.** Self-explanations are often only partially correct or even incorrect. This can lead to the construction of incorrect knowledge that, at worst, can severely impede further learning (see also Conati, 1999 Conati & VanLehn, 1999). Instructional explanations, in contrast, are in the great majority of cases correct.

2. **Solving comprehension problems.** When confronted with new information, learners frequently have comprehension impasses that they cannot resolve on their own. External help is sometimes necessary to overcome problems in understanding.

3. **Comprehension monitoring.** Learners have the metacognitive problem that they frequently have the illusion of understanding when explaining the solutions of worked-out examples to themselves (see above). As a consequence, they do not try to deepen their understanding further although this would be necessary for effective learning. Instructional explanations can show the learners, at least in some cases, that they do not yet have the sufficient understanding required to solve related problems.

With respect to these arguments, instructional explanations can be helpful. They can effectively support the learners’ knowledge-construction activities. Thus, the challenging task is to find ways to join self-explanations and instructional explanations in a way that combines their respective advantages. Based on this theoretical reflection, a set of instructional principles called SEASITE (self-explanation activity supplemented by instructional explanations) has been developed.

### 4.2. The SEASITE principles

These principles comprise two more general guidelines for an example-based learning environment and four specific guidelines for the design of instructional explanations.
1. **As much self-explanation as possible, as much instructional explanation as necessary.** It is desirable that the learners actively elaborate the examples by self-explanations that are necessarily constructed out of their own prior knowledge base, integrated into ongoing cognitive activity (timing) and self-generated (see above). Furthermore, they should acquire the competence to learn effectively from worked-out examples in a self-regulating manner. Thus, the learners should rely on self-explanations as much as possible. Instructional explanations should only be provided when the learners are not able to understand the learning content on their own (solution of comprehension problems) or when they are not sure about the correctness of their self-explanations (correctness; see above).

2. **Provide feedback.** The learning arrangement should be designed in a way that will substantially reduce the learners’ illusions of understanding frequently found in these studies (comprehension monitoring). For this purpose, some intrinsic or extrinsic feedback should be available. As explained above, the employment of incomplete examples is one possible way of heightening the learners’ metacognitive awareness of their comprehension problems (see Stark, 1999). The provision of instructional explanations is, of course, another instructional means that can fulfil a feedback function.

In addition to the two criteria that apply generally to such a learning arrangement, the following principles for the design of instructional explanations are postulated.

1. **Provision on learner demand.** Instructional explanations should be presented on learner demand. This should ensure that the instructional explanations are appropriately timed and are actually used in the ongoing knowledge-construction activities of the learners. The provision of explanations on learner demand can best be implemented in a computer-based learning program.

2. **Minimalism.** Explanations that are integrated in help systems of computer-based learning programs are often not used (e.g. Mandl, Gruber, & Renkl, 1992; Hofer, Niegemann, Eckert, & Rinn, 1996). This can be attributed to the fact that they often distract too much from the content presently focussed on because they are too long, too redundant, and too labour-intensive to process (cf. also Carroll, 1990). Furthermore, Conati and VanLehn (1999) found that ‘building blocks’ that were provided to construct self-explanations were ignored when they were too verbose. For these reasons, it is sensible to design very minimalist instructional explanations. This argument was backed up by pilot studies. 1

3. **Progressive help.** Of course, it is extremely important that the explanations are formulated in a way that will make them accessible to the learners. Another important point is that instructional explanations should not be ‘over-extensive’ and tell the learners things that they already know or that they do not need to

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1 Preliminary versions of the instructional explanations were tested in pilot studies. Participants (n=6) were interviewed in regards to how, in their opinion, the explanations could be improved upon. Although we tried to write brief explanations from the beginning, the participants proposed shortening them further.
know in the immediate instance. This is another reason to design explanation in a minimalist manner. More extensive explanations should only be provided when a lack of prior knowledge renders this to be necessary (adaptation to prior knowledge).

4. Focus on principles. With respect to the content of instructional explanations, it is argued that their focus should be on the underlying principles of the respective content (sub-)domain. This claim is supported by the significance of principle-based explanations when studying worked-out examples (e.g. Chi et al., 1989 Renkl, 1997b). Furthermore, as Alexander (1997) argues, learning progress from a novice stage to the stage of competence is generally characterized by the development of a principle-based understanding. In addition, a principle-based understanding is especially important for learning in well-structured domains such as mathematics (Hiebert, 1986; Renkl & Helmke, 1992 Steiner & Stoecklin, 1997) where the acquired knowledge should not be (as is very often the case) inert, but flexibly transferable (Renkl, Mandl, & Gruber, 1996).

4.3. The SEASITE principles and guidelines for online help systems

As already mentioned, the provision of instructional explanations during example-based learning can best be accomplished through a computer-based learning environment. Hence, a module that provides such explanation has some similarity with online help systems. Although both devices have different primary goals—whereas instructional explanations should enhance learning, help systems are designed to support performance or problem solving—, the validity of the SEASITE principles, especially those that are specific to the design of the instructional explanations, would be supported if they are mirrored in the literature on online help. Although a review of the research on online help would be beyond the scope of this article, we briefly discuss that the SEATSITE principles that are specific to the design of the instructional explanations are also part of guidelines for online help.

The principle provision on learner demand is also found in the principle for online help that Möbus, Pitschke, and Schröder (1992) postulated on the basis of their so-called ISPDL Theory. The authors claim that the help should be provided on learner request (principle 1). Duffy, Palmer, and Mehlenbacher (1992) even concentrate their book on online help to user-initiated help (see p. 19).

Minimalism is well established in the literature on computer-related instructional and help materials by Carroll’s (1990) prominent theory of minimalism. In addition, Anderson, Corbett, Koedinger, and Pelletier (1995) plea for minimalist explanations in computer-based tutoring. Finally, Duffy et al. (1992) claim for online help design that “...we should provide minimal, concise instruction for the user” (p. 111).

Progressive help is also a desirable feature that is mentioned by Duffy et al. (1992) in the context of minimalist help information. “Users can get more in-depth information, or elaborations, by layering the elaborations in another window” (p. 111). Thereby adaptation to the prior competence level of the users should be accomplished. The use of progressive help is also in accord with the claim of Möbus
et al. (1992) that one should not presuppose too much or not too little prior knowledge (principle 4) when providing help.

The focus on principles that is favoured in SEASITE is somewhat specific to situations in which meaningful learning is the primary goal. Online help, however, is typically used for overcoming performance problems. Nevertheless, when the goal is to provide online help information that enables the learners to cope also with related, but new problem situations (transfer), it has been found to be useful that the content of the help does not focus on the operative level (how to complete a task) but on fostering understanding (e.g. Dutke & Reimer, 2000).

In summary, the SEASITE principles that have been delineated from research on (self-) explanations are mirrored in guidelines for the design of online help. This theoretically backs-up the validity of the SEASITE principles.

5. Research questions

In the present study, it was investigated to what extent learning from worked-out examples can be fostered by the implementation of the SEASITE principles. The open questions relate not only to the overall effectiveness of such explanations but also to whether all learners profit to the same extent from such an arrangement or whether it is of special use for learners with a low level of prior knowledge. These learners may have more difficulties in their self-explanation efforts, as compared to the learners with more advanced prior knowledge and may therefore more often rely on the instructional explanations. This might lead to an aptitude-treatment effect: learners with a low level of prior knowledge profit in particular from the provision of instructional explanations. In addition, the frequency and the quality of the explanation use will be analysed in order to gain a deeper understanding of the involved processes and to obtain some hints for possible further improvements of the explanations.

Specifically, the following research questions were addressed.

1. What effects does the provision of instructional explanations have on learning? This question can be subdivided in three more fine-grained questions: (a) What is the overall effect on learning? (b) Does the effect vary depending on the required transfer distance? (c) Do especially learners with low prior knowledge profit from the instructional explanations?
2. To what extent are the instructional explanations used by the learners?
3. Can patterns of (in-) effective explanation use be identified? In other words: Can groups of learners be identified that show different profiles in the frequency of explanation use, in their prior knowledge, and their learning outcomes? If, as expected, the answer is yes, the following sub-questions are asked: (a) Do these groups differ in the perceived usefulness of the instructional explanations (which can, in turn, influence the depth of the explanation processing)? (b) Do the sub-groups differ in how extensively they use the explanations (differences in reading
time)? (c) Do the groups differ in the elaboration of the instructional explanations (quality of processing)?

6. Methods

6.1. Sample and design

Forty-eight student teachers volunteered to take part in this study, (mean age: 23.3 years; 36 female and 12 male participants). They received DM 25. The test persons learned probability calculation from incomplete worked-out examples (cf. Stark, 1999) under two different conditions. In the experimental group, instructional explanations were made available while studying the examples (n=28). In the control group, the learners were left to their own devices during the example study (n=20). In order to have a larger sample size, when only the data of the experimental participants were to be analysed (see Research Questions 2 and 3), more participants were included in this group.

6.2. Procedure

The participants worked in individual sessions of approximately 2 hours. First, a pretest on prior knowledge in probability calculation was presented. In order to provide or re-activate basic knowledge to allow the participants to understand the worked-out examples, an instructional text on basic principles of probability calculation was given to the participants. The comprehension of these basic concepts was assessed by a criterion-referenced test which was then corrected immediately. If there was a wrong answer, the experimenter gave a semi-standardized explanation and had the participant re-read the corresponding text passage. After this procedure, the participants were informed that they had time to study the worked-out examples for 45 min. In this phase, the experimental variation took place (with and without instructional explanations). The participants were instructed to think aloud during this period. According to the guidelines of Ericsson and Simon (1993), they were asked to talk aloud and verbalize anything that comes to mind. Before the study of examples, the thinking aloud procedure was trained by a simple warm-up problem. When the learners stopped talking for more than 15 s, the experimenter asked them to proceed thinking aloud by saying: “Please, continue talking”. Finally, the participants worked on a questionnaire on the perceived usefulness of the provided explanations \(^2\) and on the post-test.

\(^2\) This questionnaire also included some items on motivation. Motivational aspect are, however, not included in this study.
6.3. Instruments and materials

The instruments and materials are described according to their temporal sequence in the experimental sessions.

6.3.1. Pretest

Nine relatively simple probability calculation problems were employed as a pretest (e.g. “If you throw the dice twice, what is the probability of two sixes?”). One point was awarded for each correct item. The Cronbach Alpha was 0.75.

6.3.2. Instructional text

An instructional text that had been tried and tested in several prior studies (e.g. Renkl, 1997a,b) was employed. The text provided basic knowledge for the study of the worked-out examples, contained approximately 700 words (including formulas) and a diagram to illustrate the addition principle in probability calculation (see below). The following principles were explained in a fairly abstract manner: definition of probability \(p[\text{target events}] = n[\text{target events}]/n[\text{all possible events}]\), multiplication principle for independent events \(p[A \text{ and } B] = p[A]*p[B]\), addition principle \(p[A \text{ and/or } B] = p[A]+p[B]−p[A \text{ and } B]\), principle of complementarity \(p[\text{non } A] = 1−p[A]\). The worked-out examples and the test items were based on these principles of probability calculation.

6.3.3. Learning environment

A computer-based learning program was employed that has been originally developed by Renkl (1997a), was then modified by Stark (1999), and finally adapted to the present needs. The program presented worked-out examples from the domain of probability calculation (see Fig. 2). After some initial complete examples, blanks (in form of ‘?’s) were inserted into the solutions. The problem specification and the solution steps of each worked-out example were shown on four to five screen pages. On the first page, the given problems were displayed. The learner could read them and then go to the next page (Fig. 2 shows one such page). In the case of the first four examples, which were complete ones, the first solution step was presented in addition to the problem formulation on the second page. After inspecting this solution step, the participants proceeded to the following page where the next solution step was added, and so on. When the entire solution of a problem was presented, the first page of a new example followed on the next page. After four complete examples, the learners were ‘forced’ to calculate the next solution step on their own (or at least to make an attempt to do so) because a ‘?’ appeared instead of the numerical value. When the learners went to the next page, the complete solution step was presented so that there was feedback as to the correctness of the learners’ anticipation (see Fig. 2).

The participants were allowed to regulate the processing speed of the worked-out examples on their own. An external pacing control, for example, by fixing the presentation time for each page, would have interfered with the learners’ strategies and would have diminished ecological validity. However, in order to keep the time-
on-task for each participant constant, a study time of 45 min was fixed. Thus, when 45 min were up, the next mouse click on ‘Next’ caused a ‘Thank you’ screen to appear. The participants were informed about this procedure in advance.

Individual differences in processing speed caused the number of examples (pages) inspected by different participants to vary. In order to preclude the pitfall that the faster participants acquired a broader knowledge base through the inspection of further examples with different underlying structures, only four types of underlying structures were used. By setting a time span of 45 min, it was ensured that every participant would process more than the first four problems and thereby encounter each type of underlying structure. Hence, faster participants were confronted with many examples containing new surface features (i.e. new numbers, new objects), but not new underlying structures.

A feature that was installed only in the program version of the experimental group was an ‘Explanation’ button (see Fig. 2) that the learners could use. This button caused a very minimalist explanation to appear, which consisted only of the probability principle that was relevant to the actual solution step (see Fig. 3). When the learners deemed this hint as sufficient in order to continue in their self-explanation activities they could click on the ‘Back’ button to return to the example. The other possibility was to request more extensive support (‘More help’ button). In this case,
it was shown how the elements of the worked examples matched the formula elements and how the probability could be determined (see Fig. 4). In the program version of the control group, it was not possible to request any explanation or help.

6.3.4. Analysing the thinking aloud protocols

In a first step, the author conducted an explorative inspection of the verbal protocols. The purpose of this analysis was to see if there was evidence as to whether groups of differently effective explanation users differed with respect to the processing of the instructional explanations, especially with respect to the following aspects: adequately relating the explanation and example at hand; relating the explanation and their own comprehension difficulties; and drawing generalized conclusions from the explanations. In addition, it was planned to code the verbalizations with categories that have proven to be reasonable in coding self-explanations (cf. Renkl, 1997a,b). For the reasons why the planned analyses could not be sensibly performed see Section 7.

6.3.5. Questionnaire on perceived usefulness of the instructional explanations

The following four questions, which were to be answered on a Likert scale from 1 (‘not true’) to 5 (‘true’), assessed the extent to which the learner perceived the
provided instructional explanations as useful: (1) “The explanations were of sufficient detail.” (2) “The explanations were too abstract.” (3) “The explanations confused me.” (4) “The explanations were helpful.” After re-coding the negatively formulated items, the answers to these questions were aggregated to the scale “Usefulness of explanations” (Cronbach Alpha: 0.74).

6.3.6. Post-test
The post-test consisted of 13 items. One item was a relatively simple problem such as those employed in the pretest (‘warm up’). The other 12 items were constructed according to the following rationale: four items were identical to the first four worked-out examples with respect to the underlying structure, but the surface features were changed (i.e. objects, numbers); four items had similar surface features, but the underlying structure was changed; four items had a different structure and different surface features (they were, however, also based on the probability principles introduced in the instructional text). For the correct solution of a post-test item, two points were awarded. If at least half of the solution was correct, one point was given. Computational errors which occasionally occurred were ignored.

The first item and the four items with the same underlying structure were aggregated to a score of near transfer (Cronbach Alpha: 0.75). All eight problems with
changed underlying structure constituted a scale of far transfer (Cronbach Alpha: 0.77). For the post-test as a whole a Cronbach Alpha of 0.86 was determined.

7. Results

7.1. The effects of instructional explanations on learning

The control and the experimental group did not significantly differ with respect to prior knowledge (control: $M=5.80$, $SD=2.31$; experimental: $M=6.71$, $SD=1.84$; $t(46)=1.52$, $p>0.10$). As Table 1 shows, the learners who were given the opportunity to rely on instructional explanations (experimental group) were significantly more successful in the post-test than the participants who were left to their own devices ($t(46)=1.71$; $p<0.05$; one-tailed). Whereas the control-group learners attained 43% of all possible post-test points, the corresponding score in the experimental group was 54%. The effect size of 0.50 indicated moderate practical significance. As separate analyses with respect to near and far transfer showed, the effects were primarily due to the performance on far-transfer problems (changed underlying structure). Here, a medium effect size was found ($t(46)=1.93$; $p<0.05$; $d=0.57$). In the control group, the learners obtained, on average, about one third of the available points. The experimental participants reached almost half of the theoretical maximum. The small effect in near transfer in favour of the experimental group did not reach the level of statistical significance ($t(46)=1.16$; $p>0.10$; $d=0.34$). The lack of statistical significance is not due to a ceiling effect. Even the learners in the experimental group reached on average ‘merely’ 64% of the possible points although these post-test problems were structurally identical to the examples presented for learning.

With respect to the question of whether primarily learners with a low level of prior knowledge profit from the instructional explanations, we first determined the relationship between the pretest score and the explanation use. Learners with a low level of prior knowledge (pretest) tended to use the explanations more frequently (all episodes: $r=-0.52$; $p<0.05$; extended explanations: $r=-0.44$; $p<0.05$) and more extensively (time for all episodes: $r=-0.41$; $p<0.05$; time spent on extended explanations: $r=-0.31$; $p<0.10$). However, tests of interaction effects between prior knowledge and instructional condition with respect to the outcome variables (post-

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Means and standard deviations (in brackets) of the learning outcomes in the control and the experimental group$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control group</td>
</tr>
<tr>
<td>Post-test (total)</td>
<td>42.50 (21.19)</td>
</tr>
<tr>
<td>Near transfer</td>
<td>54.50 (26.25)</td>
</tr>
<tr>
<td>Far transfer</td>
<td>35.00 (20.22)</td>
</tr>
</tbody>
</table>

$^a$ The means correspond to the percentage of points in relation to the theoretical maximum.
test as a whole, near transfer, far transfer) yielded no significant results (all $F_s<1$). Thus, although learners with a low level of prior knowledge were the primary users of the instructional explanations there was no evidence that they especially profited from the provision of this type of explanations.

In summary, the instructional explanations fostered learning. This effect did not depend on prior knowledge, but it was confined to far transfer performance.

7.2. Use of the instructional explanations

For the analyses in this and the following section, only the data of the experimental group were used (remember that the control-group participants could not use instructional explanations). Table 2 shows that seven learners infrequently called up the instructional explanations; three persons never used them and four persons demanded them only once or twice. Eight learners showed three to five episodes in which they called up instructional explanations. A relatively high frequency of use was shown by thirteen learners (more than six episodes). The maximum was 21. On the average, the explanations were used 7.04 times (SD=5.80).

Expressed as time spent on the pages providing the instructional explanations (see Table 2), eight learners spent less than 1 min and six learners less than 2 min of the learning period (45 min) on the explanation pages. Fourteen participants devoted more than 2 min to the study of the instructional explanations. The average time spent on the explanation pages (including minimalist and more extensive explanations) was 147.64 s (SD=108.17).

Looking only at the more extensive explanations, an average use frequency of 2.96 (SD=2.97) was found. This means that in approximately 38% of the cases, the learners who looked up the first very minimalist explanation went on to the more extended explanation. Fifteen learners used the extended explanations two times or less. Five persons never used them. Thirteen learners looked them up three or more times. By looking at the time spent on the pages with the extended explanations, we obtained a mean of 86.50 s (SD=78.37).

To summarize, the data on the use of the instructional explanations showed that they were actually used, but not by all learners. About half of the learners showed

<table>
<thead>
<tr>
<th>Frequency of explanation use</th>
<th>Time of explanation use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand frequency</td>
<td>No. of learners</td>
</tr>
<tr>
<td>0–2</td>
<td>7</td>
</tr>
<tr>
<td>3–5</td>
<td>8</td>
</tr>
<tr>
<td>6–8</td>
<td>3</td>
</tr>
<tr>
<td>9–11</td>
<td>4</td>
</tr>
<tr>
<td>12–14</td>
<td>3</td>
</tr>
<tr>
<td>&gt;14</td>
<td>3</td>
</tr>
</tbody>
</table>
minimal use of the explanations. This leads to the question as to whether there were sub-groups of learners that showed differently effective patterns of explanation use.

7.3. Patterns of effective and ineffective example use

7.3.1. Determination and characterization of subgroups

We employed an exploratory cluster analysis (Ward procedure with squared Euclidean distances). Given that merely 28 persons (experimental group) could be used for this analysis, a parsimonious set of variable was selected: (1) pretest; (2) far transfer (i.e. the performance measure for which an effect of the instructional explanations had been shown); (3) number of episodes with a minimalist explanation only (without going on to the more extended explanation); and (4) number of episodes, in which the extended explanation was read in addition to the minimalist explanation. In order to prevent the situation that certain variables due to larger variances determine the cluster solution more than others, z-standardized variables were used.

The resulting dendrogram (Fig. 5) favoured a four cluster solution, because aggregating the cases in three (or less) clusters increased sharply the residual variance.

Fig. 5. Cluster analysis: dendrogram.
(intra-cluster variance). Fig. 6 shows the profiles of these four groups. A first look at the groups’ profiles suggested that their far transfer performance did not correspond to the expectations based on pretest scores. Hence, it was tested whether the groups significantly differed in their residualized far transfer performance (regression from far transfer to pretest on the basis of the total sample; N=48). This was actually the case ($F(3,24)=13.61; p<0.05$). The cluster differed strongly in the extent to which the learners showed more or less performance as expected from the pretest performance ($\eta^2=0.63$).

The learners in Cluster 1 could rely on above-average prior knowledge (pretest). The far transfer performance showed no regression to the average, as expected statistically, instead rather on the contrary, this group ‘enlarged its lead’ ($z$-standardized residual: 1.13). These learners rarely relied on instructional explanations. Obviously, these persons did not need them. This Cluster was called ‘successful rare-users’.

The persons in Cluster 4 relied also rarely on the instructional explanations. They showed slightly above-average prior knowledge, but only under-average transfer performance. Their learning outcomes were accordingly much lower than expected based upon their pretest results ($z$-standardized mean residual: $-0.88$). In contrast to the persons in Cluster 1, the rare use of the explanations seemed to be dysfunctional. Thus, the persons of this group were labelled as ‘unsuccessful rare-users’.

The learners from Cluster 2 had low prior knowledge (pretest). Against this background, the almost average transfer performance was to be evaluated as good ($z$-standardized mean residual: 0.58). The above-average learning gains which were paired with above-average use, especially of the more extensive explanations, indicated productive use of the instructional explanations by these persons. In other words: the learners from Cluster 2 had low prior knowledge, were accordingly in need of support, and used the offered support in a productive manner. The persons in Cluster 2 were called ‘successful users’.

![Fig. 6. Profiles of the clusters.](image)
In Cluster 3, the achievement in the pretest as well as in the far-transfer post-test were average (z-standardized mean residuum: −0.05). The minimalist explanations were used very frequently, the more extensive explanations only to an average extent. These persons are labelled as ‘mediocre users’.

With respect to the research question as to whether differently effective groups of explanation users can be identified, it was of special interest to compare the two last groups (successful user and mediocre users). Both groups relied substantially on the explanations, but with different success. In the following, both groups are described with respect to their the specific use of the instructional explanations.

When the z-values for the explanation use are ‘re-translated’ into raw frequencies, one can see that the mediocre group had more episodes of explanation use (irrespective of type) (Table 3). This was at least descriptively true but the difference did not reach the level of statistical significance. Within this context, it should be noted that the groups descriptively differed in the number of read pages (studied examples) and, as a consequence, in the opportunities to demand help (Table 3). Relating the number of explanation demands to the number of opportunities yields that both groups relied upon an explanation in about 30% of the time (Table 3).

There were, however, differences between the successful and the mediocre users with respect to their preference of moving on to the more extensive explanations. The mediocre users usually only read the minimalist explanations (M=11.4) and rarely went on to the more extensive explanations (M=2.8; Table 3). The successful users showed a more balanced use between the minimalist explanations only and

Table 3
Comparison of successful users and mediocre users with respect to the use of the instructional explanations: means and standard deviations (in brackets)

<table>
<thead>
<tr>
<th></th>
<th>Mediocre users</th>
<th>Successful users</th>
<th>d</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of explanations</td>
<td>14.20 (4.09)</td>
<td>12.33 (3.88)</td>
<td>−0.47</td>
<td>−0.78  n.s.</td>
</tr>
<tr>
<td>Read pages</td>
<td>78.20 (25.77)</td>
<td>65.33 (9.48)</td>
<td>−0.66</td>
<td>−1.06  n.s.</td>
</tr>
<tr>
<td>Explanations per opportunity</td>
<td>30.95 (17.91)</td>
<td>28.79 (10.58)</td>
<td>−0.15</td>
<td>−0.25  n.s.</td>
</tr>
<tr>
<td>Minimalist explanations</td>
<td>11.40 (3.21)</td>
<td>5.33 (3.67)</td>
<td>−1.75</td>
<td>not sensible a</td>
</tr>
<tr>
<td>More extensive explanations</td>
<td>2.80 (2.59)</td>
<td>7.00 (3.29)</td>
<td>1.42</td>
<td>not sensible a</td>
</tr>
<tr>
<td>Usefulness of explanations</td>
<td>4.40 (0.29)</td>
<td>4.33 (0.44)</td>
<td>−0.19</td>
<td>−0.30  n.s.</td>
</tr>
<tr>
<td>Reading time per explanation</td>
<td>12.61 (6.17)</td>
<td>20.69 (3.06)</td>
<td>1.66</td>
<td>2.84*</td>
</tr>
<tr>
<td>Reading time per minimali explanation</td>
<td>8.59 (3.44)</td>
<td>7.41 (2.21)</td>
<td>−0.41</td>
<td>−0.41  n.s.</td>
</tr>
<tr>
<td>Reading time per more extensive explanation</td>
<td>17.81 (9.11)</td>
<td>25.68 (9.43)</td>
<td>0.85</td>
<td>1.31  n.s.</td>
</tr>
</tbody>
</table>

* p<0.05.

a No sensible null hypothesis can be postulated because these variables were used to determine disparate clusters.

b t-test for inhomogeneous variances, df=4.80.

c n=4 instead of 5 in the groups of mediocre users because one person did not use any more extensive explanation.
the additional more extensive explanations (minimalist explanation: $M=5.3$; minimalist-more extensive explanation: $M=7.0$).

In the following, the successful users and the mediocre users are compared with respect to the aspects mentioned in the research questions.

7.3.2. Successful users and mediocre users: perceived usefulness of the instructional explanations

It was tested to what extent the groups differed with respect to the perceived usefulness of the instructional explanations, which could influence how deeply these explanations were processed. There was, however, no such difference (Table 3). Although the absolute values of scale scores have to be interpreted very cautiously, the means of the scale ‘usefulness of the explanations’ indicated that both groups perceived them as helpful (4.33 and 4.40 respectively; possible range: 1.00–5.00). Hence, differences in the perceived usefulness were not responsible for the different effectiveness of the explanation use.

7.3.3. Successful users and mediocre users: reading time per explanation

Both groups differed substantially (and statistically significantly) in the reading time per explanation (Table 3). Whereas the mediocre users read an explanation for 13 s on the average, the successful users assigned almost 21 s per explanation. The reading time of minimalist explanation did not differ, merely the reading time for the more extensive explanation differed. Although, this difference was strong ($d=0.85$), it did not reach the level of significance due to the small sample used in this analysis. Thus, the longer reading time of the successful users had to be attributed primarily to their more frequent use of the more extensive explanations. It had to remain open whether the successful users read the more extensive explanations more extensively (a strong descriptive difference was found but yet missed reaching statistical significance).

7.3.4. Successful users and mediocre users: qualitative aspects of the explanation use

A first inspection of the protocol sections that were to be assigned to the use of the instructional explanations showed that the verbalizations were very ‘meagre’, in contrast to the other protocol sections that were, however, not directly relevant in the present context. Substantial elaborations were as good as non-existent. Instead, we found the following typical protocol sections: (1) absolute silence; (2) silence or short utterance and a monitoring statement (e.g. “Multiplication rule, o.k.”); (3) verbalization about the own action and silence (e.g. “Let me see … (silence)”; and (4) loud reading of fragments of the instructional explanations (e.g. “(silence)...total probability ... (silence)”).

Against this background, a coding of the verbalizations during explanation use and an analysis of the influence of processes during explanations use on later self-explanations were obsolete. Whereas thinking-aloud protocols have proven to be a valuable data source when analysing self-explanations during example study (e.g. Chi et al., 1989; Renkl, 1997a,b; Stark, 1999), they are obviously more or less useless.
for diagnosing the processing of instructional explanations. This leads one to the question of how the sparseness of the verbal protocols while reading the instructional explanations can be explained.

During the processing of the instructional explanations, the demand of information processing was probably very high. Working memory was presumably occupied with the following demands: (1) representation of the example’s problem formulation; (2) representation of the actual sub-goal and the corresponding operation; (3) representation of the comprehension failure (or uncertainty) that motivated the explanation demand; (4) representation of the instructional explanation; and (5) the information processing demand to interrelate the explanation, the worked-out solution, and the own comprehension difficulty. The high demand on working memory may have lead to the fact that there was no remaining capacity left for thinking aloud. This interpretation is compatible with the verbalisation model of Ericsson and Simon (1993) who remark that “... in situations where intense cognitive activity can be inferred, protocols become sparse” (p. 252). More specifically, the authors assume that for thinking aloud to occur it is necessary to hold a corresponding marker in working memory. Heavy task-related cognitive load displaces the marker, the learners cease to verbalize their thoughts. This interpretation in the sense of Ericsson and Simon is backed-up by the utterance of a mediocre user. In response to a prompt to continue talking she said: “... when I don’t say anything right now, it does not mean that I am not thinking, it only means that I am thinking intensively ...”.

8. Discussion

The main results of the present study can be summarized as follows. The instructional explanations were used only to a moderate extent, they were primarily demanded by learners with a low level of prior knowledge, and there were positive effects on far transfer performance. Two groups which rarely relied on the instructional explanations were identified. The learners of one of these groups had a high level of prior knowledge (successful rare-users) and obviously did not need the instructional explanations. The other group did not have above-average prior knowledge (unsuccessful rare-users) and the lack of use of the instructional explanations was obviously detrimental. In addition to these two groups, there were two groups with frequent use of the instructional explanations. One group of learners had low prior knowledge and used the provided help in form of both minimalist and more extensive explanations in a productive way (successful user). The other group primarily relied on the minimalist explanations and did not especially profit from the explanations (mediocre users). Finally, the meagreness of the verbal protocols during the processing of the instructional explanations indicated a heavy cognitive load or even an overload during the use of the explanations.

When taken together, this means that the present instructional explanations had some effects but their design and their use should be further optimized. There seem to be two sensible starting-points for improvement: means to increase the frequencies of explanation use; and means to enhance the quality of the explanation use.
8.1. Provision on learner demand and the problem of infrequent explanation use

Despite the infrequent explanation use, it should be emphasized that the enhancement of the learning outcomes, at least in specific learners, was not achieved by an instructional agent’s active guidance (e.g. teacher, tutorial module), but, more indirectly, by structuring the learning situation in a way that supported the self-regulated processing of the learning materials. On the one hand, this attempt is remarkable because methods to support learners in forms of self-regulation are of major educational importance. The learners can become acquainted with methods helping them to guide their processing of learning materials actively and acquire some (sub-) skills useful for self-regulated learning. On the other hand, this way of providing instructional explanations might have also contributed to their infrequent use, at least by some subgroups of learners. In addition, the specific design of the explanations might have also contributed to the problem of infrequent example use (see below: Section 8.2.).

A possibility for inducing a more frequent use of instructional explanations would be if the learning program assesses some indicators for lack of understanding and presents explanations when such indicators are detected. One such indicator could be a wrong anticipation of a to-be-determined probability (see the questions marks in the learning program, Fig. 2). The learners could be required to type in the anticipated probabilities. The program checks for correctness and decides on this basis whether an explanation is to be presented or not. In a first step, just a very minimalist explanation could be given, and the learner has a second chance to type in the correct answer. After a second error, a more extensive explanation could follow. On the one hand, this procedure would be beneficial with respect to the problem of comprehension difficulties that remain unnoticed by the learners (illusions of understanding). In addition, Conati (1999) found in her study on coached self-explanations that those learners who tended to follow the intelligent tutor’s advice showed higher learning gains. On the other hand, the amount of active self-regulated elaboration and the quality of timing (see above) can be adversely affected. An interesting question for further research is whether the ‘self-regulation rationale’ or the ‘external-regulation rationale’ for providing instructional explanations is more effective. We are currently conducting an experiment comparing self-regulated and other-regulated explanation use.

8.2. Qualitative aspects of explanation use

The sparseness of verbal protocols during the study of the instructional explanations can be interpreted as a hint that the cognitive load during the processing of the explanations was (too) heavy. This interpretation can also be supported by the findings on the split-attention effect that were obtained in research on Sweller’s Cognitive Load Theory (e.g. Sweller et al., 1998). From the Cognitive Load point of view, the present explanations were sub-optimal and imposed an unnecessary cognitive load because they were displayed on separate pages and, therefore, apart from the example at hand (see Figs. 2–4). This requires the learners to keep a rep-
representation of the example’s problem formulation and of the actual sub-goal with the corresponding operator in working memory. These circumstances could have made it difficult to map the elements of the minimalist explanations (principle) to the elements in the examples. In turn, this might have also reduced the frequency of explanation use.

Further evidence for the sub-optimal design of the minimalist explanations stems from the finding that the successful users in comparison to the mediocre users more often went on to the more extensive explanations which—in contrast to the minimalist explanations—explicitly showed how the elements of the principle and of the example corresponded. Against the background of the preceding interpretation, it can be argued that the moderate learning outcomes of the mediocre users can be explained by the fact that they could not always infer the relationship between principle and example when studying the minimalist explanations due to cognitive overload.

One possibility for facilitating the mapping between the elements of the examples and of the explanations would be to use an integrated format (cf. Sweller et al., 1998). Such a format would also be compatible with recommendations found in the literature on online help. For example, Duffy et al. (1992) claimed that help information and the application (in our case: example) should both be simultaneously present.

Fig. 7 shows how this could be realized for the minimalist explanation. The more extensive explanation, which would additionally include the worked-out solution of this step, would be designed in a similar manner. This way of providing instructional explanations would have the potential to improve the qualitative aspects of the explanation study because unnecessary load induced by the former split-attention format is avoided and the arrows (see Fig. 7) help to map the elements of the example and of the principle. Presently, we are conducting an experiment in which these assumptions are being tested.

8.3. Revision of the SEASITE principles?

In the preceding discussion, two modifications have been proposed that might lead to better explanation effects: other-regulated provision of explanations and integrated format. This suggests modifying the SEASITE principles in two respects. First, the principle of provision on learner demand is to be replaced by provision on indicators of lacking understanding and, second, the principle ‘integrated format’ is to be supplemented. As mentioned above, two experiments are presently being conducted which are investigating whether the corresponding changes lead to better learning outcomes. Hence, before actually changing the SEASITE principles, we will wait until the results of these experiments are available.

8.4. Relevance of the findings to the design of explanations in general

A question that might arise with respect to the minimalist explanations and the more extensive, but still ‘lean’ explanations described in the present study is whether
they can still be called explanations. In common sense terms, an explanation comprises some ‘prose’ including terms such as ‘because’ or ‘so that’. Actually, this is what usual instructional explanations look like. We, however, deleted all prose from the explanations on the basis of pilot studies (see Footnote 1). Thus, intuitively the explanations in our study were not real explanations.

An explanation in science is, however, differently conceptualised. It is usually defined with reference to the Hempel–Oppenheim schema. An event (explanandum) is explained with reference to a law or rule (explanans) and a statement that suitable initial conditions are given so that the law or rule is relevant. Insofar, our more extensive explanations can be seen as ‘real’ explanations in the sense that they show which rule is relevant and that a connection between the rule and the specific case can be established. The (old ‘split-source’) minimalist explanations are in a certain sense just ‘half’ explanations because they state the rule to be applied but fail to show the connection between the specific case and the rule. The latter aspect should have been supplemented by self-explanation activities of the learners. To summarize: Although the present explanations can be seen as ‘real’ explanations or at least as building blocks of an explanation (‘old’ minimalist explanations) in a scientific sense, they are different from most everyday explanations in educational settings. In-so-far the present results have to be cautiously generalized to other types of explanations.
8.5. Conclusion

The present article dealt with the non-trivial problem of providing effective instructional explanations during example-based learning. For this purpose, a set of instructional principles was formulated. Explanations that were structured according to these principles had some positive effects, but the effects were far from being satisfying. From analysis of the explanation use, proposals were outlined as to how to further improve instructional explanations during example study. The question of to what extent these proposals will lead to more favourable effects needs to be clarified in further studies.

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References


