LEARNING WITH INTERACTIVE ANIMATED WORKED-OUT EXAMPLES IN GROUPS OF TWO

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This exemplary case study describes the learning process of two sixth-graders that learn from an animated worked-out example and an accompanying self-explanation prompt in the domain of fractions. It is based on a corresponding field study. The analysis focuses on the interaction with the computer, the communication between the students, the metacognitive aspects of the learning process and self-explanations. Supported with quantitative data, the qualitative results show that worked-out examples are proper materials for learning in groups of two. Furthermore, it is shown that self-explanation prompts have positive effects on the learning process and the analysed aspects. With detailed scenes it is elucidated, how the interactive capabilities and the animations are used during the learning process.

WORKED-OUT EXAMPLES

Studying worked-out examples is a well-known method for novices to increase their knowledge (Sweller & Cooper 1985). A huge body of research has shown the positive effects on knowledge acquisition and learning, whereat it often focuses on a single learner, who processes an example silently and alone. Only a few studies examine, how worked-out examples can be processed in groups (e.g. Retnowati, 2010). These studies emphasize quantitative aspects, but neither give detailed insight into the learning process nor consider differences in communication processes or learner behaviour when interpreting the results. There are different research findings about the role of *animated worked-out examples* in abstract domains (e.g. Tversky et al., 2002). A plausible position seems to be that such examples should be used, if a content analysis reveals benefits of a dynamic presentation (Höffler & Leutner, 2007).

SELF-EXPLANATIONS

The use of cognitive learning strategies has a crucial influence on the learning of mathematics (Murayama, 2012). Especially, when students learn from worked-out examples, they often do not apply meaningful strategies, but process the examples in a superficial or passive way (Renkl, 1997). *Self-explanations* form one class of cognitive learning strategies. A self-explanation is defined as

> a constructive activity that engages students in active learning and insures that learners attend to the material in a meaningful way while effectively monitoring their evolving understanding. (Roy & Chi, 2005, p. 272)

Research about worked-out examples and self-explanations shows that self-explanations are a main predictor for the learning outcome (Chi, 1989; Renkl,

2014. In Nicol, C., Oesterle, S., Liljedahl, P., & Allan, D. (Eds.) Proceedings of the Joint Meeting of PME 38 and PME-NA 36,Vol. 5, pp. 81-88. Vancouver, Canada: PME.

1997). Several concrete self-explaining processes in the domain of mathematics are integrating textual, iconic and symbolic representations (e.g. equations), goal-operator combinations and the determination of assumptions and special cases (e.g. dividing by zero). To encourage learners to learn actively and meaningfully, several methods of eliciting self-explanations and their implications on learning outcome and transfer have been analysed (e.g. Chi et al., 1994). A successful method is the use of open self-explanation prompts. These prompts are short questions or impulses that focus on key-concepts of the material or common misconceptions, or ask the learners to explain the presented procedure in their own words. The effect of self-explanation prompts on the processing of static examples is well known, whereas little is known about the combination of animated worked-out examples and self-explanation prompts (Betrancourt, 2005; de Koning, 2011).

Self-explanations are activities inside the learner's head – hence, they cannot be observed directly. However, verbal and nonverbal data can provide more or less obvious hints that allow the researcher to characterize the underlying cognitive processes (Chi, 2000). To distinct self-explanations from the observed phenomena, this paper uses the following definition: If a phenomenon (an utterance, gesture, action, etc.) gives rise to the interpretation that an underlying cognitive process is a self-explanation, this phenomenon is called a *projection of a self-explanation*.

METACOGNITIVE PROCESSES

The given definition of self-explanations names the importance of *monitoring* processes – without being aware of the need for an explanation, the learner probably will not give a self-explanation (Chi, 1989). Other important metacognitive strategies are planning and regulating (Pintrich, 1989). *Planning* means to organize the learning process. Possible manifestations are identifying task-requirements or formulating learning strategies. *Regulations* are alterations of the learning process like asking the partner or the teacher for help, or restructuring the learning process or details of it. An important group of regulations when considering learning processes with interactive animated learning material are meaningful interactions with the material such as controlling the pace of an animation or skipping animation-steps (Kettanurak, 2001). While metacognitive processes are often measured in studies concentrating on self-explanations, the concrete learning process and the effects of prompts on the metacognitive behaviour of students is rarely analysed.

CONCEPTUAL FOCUS AND RESEARCH QUESTIONS

From the former mentioned research gaps, we formulate two questions that should lead the analysis of the following case study.

- What characteristic patterns and behaviour can be observed concerning computer-interaction, metacognitive processes and communication between students, when animated worked-out examples and self-explanation prompts are processed in dyads?

- How does an open self-explanation prompt affect the processing of the interactive animated worked-out examples in dyads, the metacognitive processes and the occurrence of self-explanations?

SUBJECTS AND MATERIALS

To answer the research questions, a field study with 85 sixth-graders from three classes of a German middle school was conducted (Salle, in press). The students of one class worked with interactive animated worked-out examples in a self-regulated learning scenario and accompanying open self-explanation prompts (cf. Salle, 2013).

Materials

The used fractions curriculum focuses on the construction of concepts by connecting the mathematical characteristics of fractions to meaningful activities and familiar real world situations to enable the students to operate flexibly in a syntactic and semantic way (English & Halford, 1995). One part of this curriculum deals with reducing of fractions. On an iconic representation level, this transformation is visualised by altering the equal segmentation of a given figure. To connect the symbolic operation of reducing to its dynamic iconic counterpart, an interactive animated example was designed (Figure 1). The accompanying prompt reads: "What is the meaning of 'altering a segmentation'? What changes, what remains?"

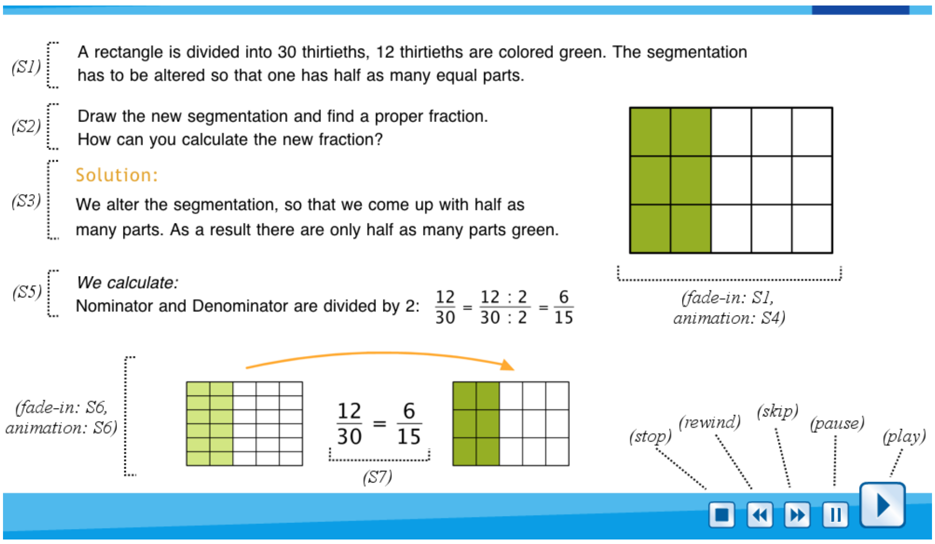

Figure 1: Screenshot after the last step of the interactive animated worked-out example *(dotted lines and italicised text in parentheses added as explanation for the reader)*.

The solution is divided into 7 segments: the context with the rectangle on the right (S1), the task (S2), the fade-in of the first part of the solution-text (S3), an animation of the altering of the rectangle (S4), the fade-in of the equation (S5), an animation of the arrow-scheme (S6) and the last equation (S7). By highlighting certain words and fractions with boxes during the animation, the dynamic processes are connected to the textual and symbolic representations. With a bar of control-buttons the students can control the different steps of the animated worked-out example.

QUANTITATIVE RESULTS

The example processing can be partitioned into a three-phase structure that could be derived from the data of the field study. In the *first phase* the students process the worked-out example without noticing the prompt. In the *second phase* they read the prompt and process it. In the *third phase* the students write down an answer. This sequence occurs in about 95% of all cases from the analysed class (Salle, in press).

Various quantitative results of this field study are published in Salle (2013), especially concerning the observed argumentation processes. The coding of metacognitive processes, self-explanations and argumentation processes shows the influence of the prompt and the differences between the phases (Figure 2). A comparison of phase one with phase two and three reveals obvious increases after the transition to the prompt-centred phases in all diagrams. Furthermore, especially questioning and reasoning statements increase in the latter phases and shape the content-related dialogues between the learners.

Figure 2: Quantitative results of the average number of coded metacognitive processes, self-explanations and argumentation processes.

The presented case of Ayla and Elli is chosen out of the transcribed learning processes of the analysed class because it contains exemplary aspects with regard to the research questions. Only phases one and two are considered in the following section, because these two phases reveal most of the aspects concerning the research questions. Due to the limited space, parts from the whole transcript are depicted, followed by a short description. Finally, the whole phase is summarized.

THE CASE OF ELLI AND AYLA

Elli and Ayla are two female students of the described class. The duration of their content-related dialogues during the processing of the examples is average. During the processing of the self-explanation prompts, they show the second longest duration in their class. The quantitative data of the girls' metacognitive processes, self-explanations and argumentations show average results related to their class.

Phase 1

Ayla and Elli start to process the described interactive animated worked-out example:

1 **Ayla**: (*with context on screen, Ayla hits the play-button, segment S2 – the task –*

appears. Immediately, she hits the play-button again, segment S3 with the first two lines of the solution appears.)

Elli: *(reads the example)* Draw the segmentation...

Ayla: (*moves the cursor above the play-button. Then she hits the play-button, segment S4 with the first animation begins, the part half as many parts is highlighted.)*

Elli: No, hold on a second... *(Meanwhile, the animation starts. Several lines of the iconic representation of the 12 thirtieths disappear successively.)*

In this short part from phase one, the two students follow the interactive animated worked-out example. Ayla controls the mouse and clicks on the play-button to start the segments of the example (line 1). Elli reads a short part of the text, but before she finishes, Ayla moves to the next segment and starts an animation (5-7, see S4 in Figure 1). Elli asks Ayla to hold on, obviously because Elli hasn't finished reading (8).

Summary of the first phase: Either the two students process the example silently or one of them is reading the text aloud. At the beginning of their processing, different processing paces can be observed. But with ongoing time, they coordinate their learning process and read the same segments ("hold on a second"). The girls process the example in linear fashion – the succession of segments is not interrupted. In the whole first phase only the play button is used. No projections of self-explanations can be observed. Their behaviour can be characterised as passive and receptive. After the last segment, the students read the accompanying open self-explanation prompt.

Phase 2

Elli: (*while both girls are looking into their workbook, Elli reads*) Open the computer-example. Try to comprehend every example-step. Then answer the following question … What is the meaning of 'altering a segmentation'? What changes, what remains?

Ayla: (*looks up*) I can't do that.

Elli: (*looks into her workbook*) Well, look. What is the meaning of 'altering a segmentation? What changes, what remains? (*looks up at the computer-screen*) Ok, look, here is something changing. (*grabs the mouse and hits the rewind-button several times*.)

When Ayla hears the questions of the prompt, she states that she "can't do that" (14). Elli tries to find something that helps to answer with the prompt (15-16). Simultaneously, she addresses her words to Ayla to involve her in the conversation (e.g. "Well, look", 17). Elli does not want to surrender too early. She grabs the mouse and rewinds some segments to navigate to a part of the example. There she discovers "something changing" that could help with answering the prompt (17).

After the depicted scene, the two girls continue their approach to the prompt-answer and repeat the animations. Then they stay at a point, at which the lighter green pieces become darker in an animation (can be seen in the smaller left and right rectangle).

Ayla: Hm? That doesn't make sense. This has only changed its color.

Elli: (*hits the play-button, segment S5 – the calculation – appears*) That has become darker .. And then, here. In absolute terms, numerator and denominator are divided by two … throughout by two, by two, by two..

Ayla: Ah, ok, now. That's because herein are such strange lines.

Elli: (*looks up*) Yes. (*5 seconds pause*) Whatever. Divided by two, hm? .. Because, …, because one box (*forms a rectangle with her hands*), there were two boxes in it. Then, they removed the line there (*the back of one flat hand touches the palm of the other, then she separates them vertically*) and then there was a very big box, now again. And, uhm, then they have, .. two, well, divided against [sic!] two. 12 divided by 30, why 30? (*2 seconds pause*) One two three ... Ah yes! (*then she speaks a bit slower*) because previously there were 30 (*moves her fingers in circles*).

After an animation step (S5), Ayla is confused concerning the graphical alteration of the pieces (19). Simultaneously, this is a specific monitoring statement – she expresses which part of the animation does not make sense to her. Elli describes, that on a computational level, "numerator and denominator are divided by two" (21-22). She repeats "by two" three times, obviously to clarify that there are more dividing-processes than one (22). Ayla gets the point and connects Ellis explanation to the "strange lines" in the animation (23). Then Elli explicates her first utterance by an explanation how two rectangles were put together to one (25-29). During this explanation, she uses her hands to form a rectangle and to visualize the removal of the lines. Finally, she successfully connects the rectangle-pieces to the fraction (30).

Summary of the second phase: The second processing-phase is characterised by a much more active behaviour of the two students. They regulate their learning process frequently by using the control-bar to navigate through the example, try to identify relevant information with regard to the prompt and make their partner aware of this information. The reading of the prompt oftentimes causes immediate monitoring utterances ("I can't do that", 14). Various projections of self-explanations can be observed – *verbal projections* (e.g. "by two, by two, by two" (22) suggests that she breaks the division down into a division of pieces) as well as *nonverbal projections* (imitating a rectangle and the altering-process with her hands). In following scenes, Elli continuously uses gestures to imitate depicted processes or to clarify aspects. Elli explains the altering-process in her own words and does not need to use the example to refer to it.

RESULTS

The case study of Ayla and Elli is exemplary in many aspects with respect to the analysed class that worked with open self-explanations in groups of two. In the following section, I refer to characteristic results of the whole class.

Characteristic patterns and behaviour during example processing: The *first* phase is characterised by a passive and receptive processing of the steps of the animated examples. Observed regulations are often adjustments of the processing pace, only in a few cases segments are rewinded or skipped. Mostly, they are followed in a linear way. The students follow the steps silently, or one of them reads out the text aloud. Monitoring statements are often unspecific. Only a few self-explanations can be reconstructed, a focus on special aspects of the content is identified seldom. With respect to the new content of the example, this behaviour could be expected.

The *second* phase is shaped by lots of student activities. Many more of the monitoring statements are specific ones. Meaningful interactions with the animated worked-out examples can be observed frequently – with concrete aims in mind, the students use the buttons to navigate through the examples, heading for various segments or animations. The students talk much longer than in phase one – explanations, argumentative and coordinative statements are verbal features of their learning process. These utterances are often induced by parts of the prompt questions that want the students to explain or to reason. Many more self-explanations can be reconstructed from verbal as well as nonverbal projections than in the first phase. These cognitive activities focus on key-concepts of the depicted solution. During this lasting involvement in the example- and prompt-processing, the students can organise the depicted processes more and more mentally without referring to the animations.

Effects of the open self-explanation prompts: Having watched the entire animated example in phase one, the first contact with the self-explanation prompt constitutes a caesura in the learning process. The prompt-question induces content-related conversations, especially argumentations, explanations and coordinative dialogues (Fig. 2, see also Salle, in press). The whole learning process is more focussed towards key-concepts and -principles. Self-explanation prompts serve as focal points and support students during the engagement with the examples. Only a few seconds after reading, the students often utter monitoring statements and self-explanations. This can be reconstructed in many transcripts. Subsequently, they navigate through the examples and break through the linear, superficial and passive processing of the first phase. Altogether, self-explanation prompts foster meaningful, active and self-regulated learning, content-related talk and argumentations during the learning with animated worked-out examples.

PERSPECTIVES

This paper shows the different positive implications that learning with animated worked-out examples and open self-explanation prompts can have despite their well-known properties. Nevertheless, a lot of questions remain unanswered and further research is needed to shed more light on cooperative learning from worked-out examples and the implications that prompts, trainings or design features of examples have on the learning process.

References

Betrancourt, M. (2005). The Animation and Interactivity Principle in multimedia-learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 287-296). Cambridge, UK: Cambridge University Press.

Chi, M. T. H. (2000). Self-explaining expository texts. In R. Glaser (Ed.), *Advances in instructional psychology* (pp. 161-238). Mahwah, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, *13*, 145-182.

Chi, M. T. H., de Leeuw, N., Chiu, M.-H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science*, *18*(3), 439-477.

De Koning, B. B., Tabbers, H. K., Rikers, R. M. J. P., & Paas, F. (2011). Improved effective-ness of cueing by self-explanations when learning from a complex animation. *Applied Cognitive Psychology*, *25*(2), 183-194.

Höffler, T. N., & Leutner, D. (2007). Instructional animation versus static pictures: A meta-analysis. *Learning and Instruction*, *17*(6), 722-738.

Kettanurak, V., Haseman, W. D., & Ramamurthy, K. (2001). User attitude as a mediator of learning performance improvement in an interactive multimedia environment. *International Journal of Human-Computer Studies*, *54*(4), 541-583.

Murayama, K., Pekrun, R., Lichtenfeld, S., & vom Hofe, R. (2012). Predicting long-term growth in students' mathematics achievement: The unique contributions of motivation and cognitive strategies. *Child Development*, *84*(4), 1475-1490.

Pintrich, P. R. (1989). The dynamic interplay of student motivation and cognition in the college classroom. *Advances in Motivation and Achievement*, *6*, 117-160.

Renkl, A. (1997). Learning from worked-out examples: A study on individual differences. *Cognitive Science*, *21*(1), 1-29.

Retnowati, E., Ayres, P., & Sweller, J. (2010). Worked example effects in individual and group work settings. *Educational Psychology*, *30*(3), 349-367.

Roy, M., & Chi, M. T. H. (2005). The Self-Explanation Principle in multimedia-learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 272-286). Cambridge, U.K.: Cambridge University Press.

Salle, A. (2013). Reasoning with animated worked-out examples. In A. Lindmeier & A. Heinze (Eds.), *Proc. 37th Conf. of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 137-144). Kiel, Germany: PME.

Salle, A. (in press). *Arbeitsverhalten und Argumentationsprozesse beim Lernen mit inter-aktiven animierten Lösungsbeispielen.* Bielefeld, DE: Universität Bielefeld.

Sweller, J., & Cooper, G. (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction*, *2*(1), 59-89.

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: can it facilitate? *International Journal of Human-Computer Studies*, *57*, 247-262.