Computer-based Problem Solving to Prepare for Adaptive Consolidation

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Abstract: During problem solving prior to instruction, students usually generate erroneous solution attempts, which can form the basis for acquiring valid concepts during subsequent instruction, if students are prompted to compare correct and incorrect examples. In a previous study, these prompts were only beneficial if the incorrect examples resembled students' own attempts. Therefore, a computer-based version that would allow for adaptation of the instruction is tested with regard to the similarity of students' products and difficulties.

Introduction

Research on productive failure has shown beneficial effects of problem solving prior to instruction on conceptual understanding compared to instructional designs with the reverse order of the learning phases (e.g., Kapur, 2010). However, Loibl and Rummel (2014) showed that students engaging in problem solving prior to instruction outperformed their counterparts with respect to conceptual knowledge only when the instruction compared typical erroneous student solutions to the correct solution. Similarly, Loibl and Leuders (2018) showed that students who were prompted to compare solution attempts performed best at posttest. This effect was highest for students whose initial solution attempts were similar to the incorrect examples of the consolidation phase (Loibl & Leuders, 2019).

These findings call for adaptively taking students' solution attempts into account in the design of the instruction phase. This adaptivity could potentially be reached in a computer-based system. However, converting paper-based learning materials in a computer-based system may alter the learning processes and products: „Computational transposition is a process that occurs during the design and implementation of computer learning environments with the potential for significantly transforming the knowledge to be taught by these means" (Hoyos, 2016, p. 139). As the finding regarding the importance of the fit between students' attempts and the instruction was found with paper-based materials, a first step towards an effective adaptive system requires to focus on the problem solving phase and to validate that the computer-based implementation allows the same types of products and the same categories of difficulties as the paper-based version.

We tested this assumption in a collaborative setting for two reasons: First, most research on productive failure has been implemented in collaborative settings (e.g., Kapur, 2010; Loibl & Rummel, 2014). Second, the natural verbalization of ideas and difficulties in a collaborative setting allows for in-depth analyses of the learning process.

Research question

We investigate the question whether a collaborative computer-based implementation of the problem-solving phase, allows the same types of products and the same categories of difficulties as the paper-based version.

Methods

Participants

28 fifth-graders (i.e., one class) used the computer-based system in pairs. Based on their solution attempts five pairs were selected to additionally participate in an interview regarding their experiences and difficulties.

Learning material and computer-based system

The learning unit covered comparing fractions. The present study focused on the problem-solving phase only. All students were asked to decide which team wins a scoring contest where each player attempts to score a goal once: a team of 5 girls who scored a total of 3 goals or a team of 10 boys who scored a total of 5 goals. It was clarified that each team member only had one attempt. During the problem-solving phase students worked on a computer. The computer-based system included a task description and an applet. The applet allowed students to generate fractions bars with any number of parts. The sizes of the parts had to be selected one by one, thus, allowing the typical errors of unequal parts. In addition, students could color the parts.

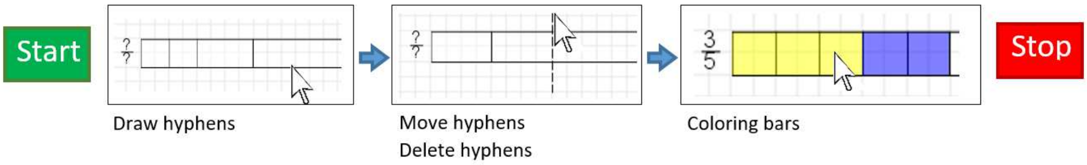

Figure 1. Possible actions in the applet.

Coding scheme

We analyzed the screen recordings and interview data two-folds. First, we coded whether the seen or reported difficulties stemmed from the problem-solving task or from the use of the computer. Second, we coded the incorrect solution attempts based on the coding scheme from Loibl and Leuders (2018).

Procedure

The study started with an activation of prior knowledge about fractions. Afterwards, the experimenter introduced the applet and tried to eliminate any difficulties that may result from the unfamiliar use of computers. Afterwards the problem-solving phase started with a short verbal introduction of the problem to ensure that all students understood the cover story and the question to be worked on (i.e., fair comparison on which group wins). During the problem-solving phase, students worked in pairs on one computer. Students' utterances and their screens were recorded. Based on the solution attempts, five pairs were selected for in-depth interviews. These interviews used the stimulated recall technique.

Results

36.99% of the difficulties stemmed from the use of the computer and 63.01% difficulties related to the content or the task. All incorrect solution attempts could be assigned to one of the categories found with the paper-based version. Table 1 compares the relative frequency of categories of incorrect solution attempts between the paper-based version (cf. Tab. 5 in Loibl & Leuders, 2018) and the computer-based system.

Table 1: Differences in frequency of incorrect solution attempts

	Paper-based version	Computer-based system
Special non-generalizable strategy	7,53%	18,92%
Absolute frequency without notion of relativity	48,39%	29,73%
Argumentation with only one component	27,96%	16,22%
Unclear or non-mathematical strategy	13,98%	24,32%
Correct solution	2,15%	10,81%

Discussion

Our results show that students generated similar products in our computer-based system as shown with the paper-based version by Loibl and Leuders (2018). Thus, a future adaptive system can build on previous results and prompt comparisons between correct and incorrect examples by selecting the examples based on students' own attempts. However, our results also show that students encountered additional difficulties that stemmed from the system. While this finding is not surprising, given that this version was a low-integrated pilot, it highlights the need to refine the system substantially to allow for a more smooth application.

References

Hoyos, V. (2016). Distance technologies and the teaching and learning of mathematics in theeEra of MOOC. In: M. Niess, S. Driskell, & K. Hollebrands (Eds.), *Handbook of research on transforming mathematics teacher education in the digital age* (pp. 137–164). USA: IGI Global.

Kapur, M. (2010). A further study of productive failure in mathematical problem solving: Unpacking the design components. *Instructional Science, 39(4*), 561-579.

Loibl, K., & Leuders, T. (2018). Errors during exploration and consolidation – The effectiveness of productive failure as sequentially guided discovery learning. *Journal für Mathematik-Didaktik, 39*(1), 69-96.

Loibl, K. & Leuders, T. (2019). *How to make failure productive: Fostering learning from errors through elaboration prompts.* Manuscript submitted for publication.

Loibl, K., & Rummel, N. (2014). Knowing what you don't know makes failure productive. *Learning and Instruction, 34,* 74-85.