Learning in mathematics: Effects of procedural and conceptual instruction on the quality of student interaction

Dejana Diziol[1], Nikol Rummel[1], Hans Spada[1], & Stephanie Haug[2]
Institute of Psychology, University of Freiburg, Germany
Email: [1]{diziol, rummel, spada}@psychologie.uni-freiburg.de
[2]stephanie.haug@web.de

Abstract: Quantitative analyses from our previous research indicated that collaboration is more effective when learning with conceptual instruction than when learning with procedural instruction. To explain this differential effect, we analyzed student interaction during instruction. First analyses show that the conceptual instruction elicited more fruitful interaction behavior than the procedural instruction. Furthermore, in the procedural condition, students more often split potential learning opportunities between each other, yielding decreased practice opportunities.

Introduction

While research has generally shown that collaboration may facilitate student learning in mathematics, such positive effects are not always found (Lou et al., 1996). Quantitative analyses from our previous research indicated that the impact of collaboration may depend on the type of knowledge students are expected to acquire during the interaction (Diziol, Rummel, & Spada, 2010). The study compared the effect of four conditions on student learning in mathematics. In two procedural conditions, students learned the execution of computational procedures that are necessary to solve equations; in two conceptual conditions, students learned to translate between verbal and algebraic representations of basic mathematical concepts. During instruction, students worked either individually or collaboratively. Post-test results indicated a differential impact of collaboration on the individual learning outcome: When learning with procedural instruction, collaboration impeded student procedural knowledge acquisition compared to individual learning; when learning with conceptual instruction, collaboration improved students' conceptual understanding. Furthermore, collaboration had a different influence on student learning behavior during instruction depending on the type of tasks they solved. As indicators for student learning processes, we assessed the time students spent prior to problem-solving steps and the time after errors. While collaboration reduced the time prior to steps for procedural instruction, it increased the time prior to steps and after errors for conceptual instruction. How can this differential impact of collaboration be explained? Following the interaction paradigm introduced by Dillenbourg, Baker, Blaye, and O'Malley (1996), we argue that the different task types that students worked on during instruction elicited different types of interactions, and that the elicited interactions were not equally effective to promote student learning. To evaluate the influence of the instruction material on student interaction, we analyzed student learning processes during instruction. The results of these process analyses can help to increase our understanding of when and why collaboration is helpful.

Evaluation of students' learning processes

Seventy-nine high-school students were randomly assigned to four conditions: individual vs. collaborative learning with procedural instruction, and individual vs. collaborative learning with conceptual instruction. During instruction, students worked in a computer-supported learning environment on linear algebra problems. The instruction alternated between worked examples and tutored problem-solving. During tutored problem-solving, the learning environment provided immediate feedback to student actions: Errors were marked in red, and correct answers were marked in green. To ensure that students would not get stuck, the learning environment automatically launched a hint after the third incorrect student attempt which told students the correct solution to the problem-solving step. The procedural and conceptual instruction differed in the following way: In the procedural conditions, students learned to solve linear equations. In the conceptual conditions, students derived linear equations from story problems. To enable the comparison of learning processes of individual students and collaborating dyads, half of the students in both the procedural individual and the conceptual individual condition received additional instruction to think aloud during problem-solving, and we recorded both audio and video data and students' problem-solving actions (log data).

To compare students' learning processes during instruction, we developed a coding scheme that evaluates student behavior after making errors and receiving hints. Earlier studies have shown that errors and hints are important learning opportunities in tutoring environments; however, students do not always take advantage of these opportunities. Two ineffective learning strategies are trial and error, and hint abuse (i.e. students merely copy the correct answer from the hint). In contrast, it is more fruitful for learning if students elaborate on how to correct an error or if they try to understand the solution step proposed by a hint, and particularly the mutual elaboration with a learning partner can promote students' knowledge acquisition. For student behavior following errors, we classified for each error whether students were able to correct the error, whether they engaged in the ineffective trial and error strategy, or whether they elaborated on the error (*learning processes dimension*; for an overview of the categories, see Table 1). For student behavior following hints, we classified for each hint whether students engaged in hint abuse, whether they elaborated on the hint, and whether they were able to understand it. In the collaborative conditions, we furthermore analyzed if both students capitalized on the learning opportunity (*interaction dimension*): Did they collaborate to correct the error or to understand the hint, was only one student responsible for the action following the error or hint, or did they not discuss the error or hint at all? We expected that students particularly benefit from collaboration if they interact with each other, while they may not benefit from the learning opportunity if they are not both engaged in problem-solving. We implemented the coding scheme with Activity Lens (Avouris, Fiotakis, Kahrimanis, Margaritis, & Komis, 2007). By combining log data from the learning environment and video recordings, Activity Lens enabled us to navigate to the relevant sequences of the video for the process analysis.

So far, we concentrated our analysis on the collaborative conditions. Analyses of students thinking aloud are in progress, and results will be presented at the conference. The comparison of the two collaborative conditions suggests that the conceptual instruction elicited more fruitful learning behavior than the procedural instruction (learning processes dimension, Table 1). Dyads in the conceptual condition showed higher elaboration following errors. In contrast, dyads in the procedural condition engaged more often in ineffective learning behavior: After nearly half of the errors that were not immediately corrected, students showed trial and error behavior, and a fifth of the hints were merely copied by students. Furthermore, in the procedural condition, the learning opportunities after errors and hints were more often split between learning partners (interaction dimension): Mostly one dyad partner was responsible for the subsequent solution step (after 49 % of errors and 40 % of hints), while mutual interaction was rare (32 % of the errors and 20 % of the hints). Frequently, dyads even did not talk about the following step at all (after 19 % of errors and 40 % of hints). The consequential decrease of practice in the procedural collaborative condition can explain why these students did not profit from the interaction with a partner. In contrast, in the conceptual collaborative condition, all hints were verbally addressed by at least one student of the dyad, and in 74 % of the errors and in 62 % of the hints, students worked together to decide on the next action. Our next steps will be to statistically compare the learning processes in the four conditions and to evaluate the impact of the different learning processes on students' learning outcome. These analyses can further increase our understanding of the influence of the instruction material on the quality of student interaction and reveal when and why collaboration is helpful. At the conference, we will present the results of these analyses and discuss implications of our research for practice.

Table 1: Percentage of student behavior following errors and hints (learning processes dimension).

		procedural	conceptual
error: next step incorrect	trial and error: immediately next error	44 %	15 %
	reflection on error, without verbal elaboration	6 %	15 %
	reflection on error, with verbal elaboration	50 %	70 %
error: next step correct	immediate correction	60 %	32 %
	reflection on error, without verbal elaboration	10 %	0 %
	reflection on error, with verbal elaboration	30 %	68 %
hint	hint abuse: copying the correct step	20 %	0 %
	reflection on hint, without verbal elaboration	40 %	19 %
	verbal elaboration on hint, but step is not understood	20 %	24 %
	reflection on hint, with verbal elaboration	20 %	57 %

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