The Student Becomes the Master: Integrating Peer Tutoring with Cognitive Tutoring

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Abstract: Combining peer tutoring with an intelligent tutoring system (ITS) holds the promise of augmenting the current benefits of the ITS. We designed and implemented a peer tutoring approach as an addition to the Cognitive Tutor Algebra (CTA), an ITS for high school algebra. We then used 30 students to evaluate the potential of the peer tutoring addition to increase learning. Although students learned and interacted positively, peer tutors lacked the necessary expertise to adequately help their tutees.

Introduction

Combining collaborative activities with intelligent tutoring might be an effective way of increasing student knowledge. The guided problem-solving provided by an ITS is effective but limits student construction of knowledge, while collaborative activities increase the potential for the acquisition of deep knowledge but do not always provide sufficient guidance for students. Our work integrates collaborative learning with an ITS using a peer tutoring framework, with the goal of allowing students to tutor each other through the interface of an ITS, supported by both cognitive and collaborative tutoring. However, implementing a peer tutoring script within the context of an existing ITS may not require much computer tutoring to be effective, for two reasons: Students who have used the ITS already have a mental model for how the cognitive tutoring works in the ITS, making it easier for them to assume the tutoring role, and as the student interaction is structured through the interface of the ITS, it might be easier to implement script elements than if students were interacting face-to-face. Additional cognitive and collaborative tutoring would only be necessary if students do not comply with the script. Therefore, our first step is to implement a baseline peer tutoring condition within the context of an existing ITS: the Cognitive Tutor Algebra. We use the interface of the ITS to structure the interaction between the students, but we do not provide hints and feedback to the students as they collaborate. The effectiveness of this condition at increasing learning will indicate whether and how to provide adaptive support.

Script Design and Implementation

We incorporated elements of previous successful peer tutoring scripts into our intervention. Peer tutoring has been shown to be effective when students exhibit certain behaviors. Asking specific questions, receiving elaborated explanations, and using those explanations constructively have been correlated with tutee learning (Webb, Troper, & Fall, 1995). Students learn from being tutors if they prepare ahead of time (Fantuzzo, Riggio, Connelly, & Dimeff, 1992), monitor skills being acquired (Fuchs et al., 2003), and provide their partners with elaborated explanations (King, Staffieri, & Adelgais, 1998). Biswas, Schwartz, Leelawong, Vye, and the TAG-V (2005) identified three aspects of learning interactions that seem to explain the benefits of learning by teaching: students take responsibility for, reflect on, and structure their knowledge.

In our peer tutoring script, students are given a task like “Solve for x,” for an equation like “ax + by = c.” Students go through two phases: a preparation phase and a collaboration phase. In the *preparation phase*, peer tutors are given a chance to practice with the material ahead of time by solving problems using the CTA. They use an equation solver tool to manipulate the equation, and are given immediate feedback from the cognitive tutoring component of the CTA when they make a mistake. They can also ask for a hint from the CTA at any time. As they solve the problem, they are given feedback on their progress through a skillometer, which contains bars that represent their skills and change in value with correct and incorrect student actions. During the *collaboration phase*, students are grouped into same-gender pairs of similar abilities and collaborate at different computers, taking turns being peer tutors and peer tutees. Peer tutees solve the same problems as their tutor solved in the preparation phase, using the same interface. Peer tutors can see their peer tutee's actions, but cannot solve the problem themselves. Instead, they are given a printout of their own answers to that particular problem, and take the role of the cognitive tutor. They can mark the peer tutee's actions right or wrong, and adjust the values of the tutee's skill bars. There is also a chat tool, where tutees can ask questions and tutors can give explanations.

We added two additional activities to extend the script and guide students in their interaction. First, during the preparation phase, we gave students questions to prepare them for the collaborative challenges of tutoring as well as the cognitive ones (e.g., "A good question is specific. It asks why something is done, or what would happen if the problem was solved a certain way. What is a good question to ask about the step you chose in Question 2?"). Second, we gave students three additional reflection questions after they had just finished tutoring a problem (e.g., "What was the best question asked by the tutee? If the tutee didn't ask any questions, what was a good question he/she could have asked?"). We implemented the peer tutoring within the context of a more general collaborative framework added to the Cognitive Tutor Algebra (CTA).

Script Evaluation

We compared two conditions, one in which students tutored each other using the CTA interface by following the preparation and collaboration phases (the *tutoring* condition), and one in which students tutored each other using the CTA interface and were given the additional collaborative instruction described in the previous paragraph (the *tutoring+reflection* condition). We hypothesized that peer tutoring would increase student learning in both conditions, but giving students additional instruction would enhance the effects of the peer tutoring. See Table 1 for a description of the experimental procedure. To assess student learning we used a counterbalanced pretest and posttest, each containing 8 questions drawn from the same unit as the treatment questions.

Participants were 30 high-school students from two first-year algebra classes at a vocational high school. Both classes were taught by the same teacher. Due to the disruptiveness of students in the same class using different interventions, we used a between-class manipulation. The class with the most participants was assigned to the tutoring+reflection condition. Only 14 participants participated in all phases of the study (pretest, preparation for tutoring, peer tutoring, and posttest): seven in the tutoring condition, and seven in the tutoring+reflection condition. Unfortunately, there were significant between-class differences: students in the tutoring+reflection condition were working on a significantly lower unit in the Cognitive Tutor Algebra prior to the study (Ms = Unit 8.3 and Unit 11.6, SDs = 1.25 and 2.76, $F(1,12) = 8.22$, $p = .01$).

Table 1. Experimental procedure. Differences between conditions are highlighted by *italics*.

Day	Activity	Time	Tutoring Condition	Tutoring + Reflection Condition
1	Pretest	10 min.	- pretest on domain knowledge	- pretest on domain knowledge
2	Overview	15 min.	- overview of tutoring interface	- overview of tutoring interface
2	Preparation Phase	40 min.	- students solve the problems they will be tutoring	- students solve the problems they will be tutoring - *students answer reflection questions*
3	Collaboration Phase	50 min.	- students tutor each other	- students tutor each other - *students answer reflection questions*
3	Posttest	10 min.	- posttest on domain knowledge	- posttest on domain knowledge

Results

We scored the pretests and posttests on a 5 point scale. We then conducted a two-way (condition x test-time) repeated-measure ANOVA, with test-time as the repeated measure. Posttest scores were significantly higher than pretest scores in both the tutoring and the tutoring+reflection condition ($F(1,12) = 15.25$, $p < .002$, $\eta^2 = 0.56$), but there were no significant differences between conditions, and no interaction (see Table 2). To further examine what occurred during the collaboration phase we turned to log data and notes from classroom observation. During peer tutoring, students appeared engaged, and did exhibit many of the positive collaborative behaviors that we were attempting to encourage with our script and that have been shown to correlate with knowledge construction and self-reflection. However, we observed that peer tutors struggled to provide tutees with answers, and did not connect the preparation that they had done with the collaboration phase. For instance, they often did not consult their answer printouts when they did not know the next problem step and thus had to rely on teacher assistance to solve a problem. As a result, tutees skipped problems without completing them correctly. This undesirable behavior differed between the two conditions (see Table 2). Students in the tutoring condition attempted more problems than students in the tutoring+reflection condition, and appeared to complete more problems as well. The average number of problems completed by dyads in the tutoring+reflection condition was low; students in this group took an average of 11 minutes to complete a single problem, compared to a 6 minute average in the tutoring condition. Students in the tutoring condition tended to skip problems they could not solve, completing less than 60% of the problems they attempted. Immediately before skipping a problem, students would generally state their inability to solve it, "I don't know how to do this one," or their lack of motivation, "Just do something and I'll agree or something." If students skip problems, they may not learn how to solve difficult problems. However, if they do not complete many problems, they may not be sufficiently exposed to all the skills involved in the unit, and will be given fewer opportunities to master them.

Table 2. Attempted problems and interaction data for the two conditions

	Pretest Score		**Posttest Score**		**Problems Attempted**		**Problems Completed**	
Condition	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Tutoring	31.1	25.4	45.8	31.8	14.2	8.47	8.4	5.13
Tutoring + Reflection	22.9	15.3	42.8	22.0	5.8	3.11	4.4	0.89

Conclusion

Although students learned as a result of the peer tutoring, we did not find that the condition with additional tutoring instruction learned more than the condition without additional instruction. Instead, many students had difficulty following the peer tutoring script effectively. Students in the tutoring group tended to skip past problems they could not solve, while students in the tutoring+reflection condition completed fewer problems than students in the tutoring group. Increasing the number of problems that students are able to correctly complete while collaborating should improve student learning, because students will be given more of an opportunity to master the skills required by different problems. Adding adaptive feedback should allow peer tutors to more effectively and accurately help their partners.

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