17th International Conference on Artificial Intelligence in Education
Madrid, Spain, June 22-26, 2015

Adapting Collaboration Dialogue in Response to Intelligent Tutoring System Feedback

Jennifer K. Olsen[1], Vincent Aleven[1], and Nikol Rummel[12]

[1]Human Computer Interaction Institute, Carnegie Mellon University, Pittsburgh, PA, USA
jkolsen@cs.cmu.edu, aleven@cs.cmu.edu
[2]Institute of Educational Research, Ruhr-Universität Bochum, Germany
nikol.rummel@rub.de

Abstract. To be able to provide better support for collaborative learning in Intelligent Tutoring Systems, it is important to understand how collaboration patterns change. Prior work has looked at the interdependencies between utterances and the change of dialogue over time, but it has not addressed how dialogue changes during a lesson, an analysis that allows us to investigate the adaptivity of student strategies as students gain domain knowledge. We address this question by analyzing the shift in types of collaborative talk occurring within a single session and in particular how they relate to errors for 26 4th and 5th grade dyads working on a fractions tutor. We found that, over time, the frequency of interactive talk and errors both decrease in dyads working together on conceptual problems. Although interactive talk is often held as a gold standard in collaboration, as students become more proficient, it may not be as important.

Keywords: Problem solving, collaborative learning, intelligent tutoring system

1 Introduction

As students work together on collaborative problem solving, their behaviors may change over time. To understand how to best support learning with the use of technology, it is important to take this change into account so that the system can accurately adapt to the change in behaviors. This paper addresses changes in behavior that may be seen over a short period of time, namely, changes within a single collaborative learning session, which are often ignored by using an aggregate score for process data measures collected over an entire session. We focus our analysis on students' dialogue and how this is related to behavior in an Intelligent Tutoring System (ITS) designed to support collaborative learning.

Past work with Computer Supported Collaborative Learning has focused on changes over time based on interdependencies within the dialogue [1], [4], [7] and how communication changes permanently over long periods of time [3], [6]. However, neither of these perspectives takes into account how behaviors and strategies may change temporarily within a single lesson as students learn, which may show how

language is being used as a tool for learning rather than showing the learning of collaboration strategies. For our study, we analyzed collaborative dialogue within a single lesson. Within an ITS, we often use a decrease in error rate as an indication of learning. As students make fewer errors, they may feel less of a need to discuss the answer and have less interactive talk. By using errors, we are able to investigate how students adapt their use of interactive talk as needed to help them through impasses. We analyzed how interactive talk changed between the first and second half of the session and how these changes were correlated to changes in error rates.

2 Methods

We analyzed data from a study in a school in which 26 4th and 5th grade dyads, paired within a grade (i.e., 13 4th and 13 5th grade dyads), engaged in a problem-solving activity geared towards either conceptual or procedural knowledge of fractions using a collaborative ITS [5]. The problem sets offered standard ITS support (immediate feedback and hints) as well as embedded collaboration scripts supported through three different collaboration features: assigned roles, individual information, and cognitive group awareness. Each student had their own view of the collaborative ITS while they were synchronously working on a problem and communicated through Skype (audio only). Each dyad worked with the tutor for 45 minutes in a pull-out design.

We coded the collaborative dialogue using a rating scheme with four major rating categories: interactive dialogue, constructive dialogue, constructive monologue, and other. For our analysis, we focused on the interactive dialogue category, in which students engage in actions such as co-construction and sequential construction, because it aligns with ICAP's joint dialogue pattern and is held as the gold standard for collaboration [2]. Our rating scheme was developed to look at groups of utterances associated with subgoals (i.e., a group of steps that all are for the same goal within a problem) to account for the interactions between students. An inter-rater reliability analysis was performed to determine consistency between two raters (Kappa= 0.72).

In our analysis, we used two different error counts. The first was the total number of errors made on a subgoal by either student in the dyad. The second error count was the number of steps within the given subgoal that contained errors. For all variables the change was calculated by subtracting the first half value from the second half value. Since each dyad completed a different number of subgoals, from 25 to 143, the first and second halves of the session were calculated by dividing the total number of subgoals completed in half. All variables used in analysis were calculated in proportion to the number of subgoals that were completed.

3 Results

Because the procedural and conceptual tutor problems were fundamentally different with regard to the types of knowledge that were being learned, each of these conditions was treated separately. To test our hypothesis that the percent of subgoals where interactive talk occurs will change from the first to the second half of the session, we

conducted two paired t-tests, one for the procedural condition and one for the conceptual condition. For the procedural condition, there was no significant difference in the amount of interactive talk between the first (M = 0.24, SD = 0.18) and second half of the session (M = 0.21, SD = 0.19), $t(12) = 1.23$, $p = 0.24$. For the conceptual condition, there was a significant decrease in the amount of interactive talk between the first (M = 0.32, SD = 0.20) and second half of the session (M = 0.19, SD = 0.12), $t(12) = 3.50$, $p < 0.01$. There was also a significant increase in the amount of other talk between the first and second half of the session, $t(12) = -2.75$, $p < 0.05$.

To better understand how the change in interactive talk may be related to students' problem-solving behaviors with the ITS, we analyzed how our two error measures differed between the first and second half of the session. We used a paired t-test to compare the two time points. In the procedural condition, there was no significant difference in the total number of errors made between the first (M = 1.27, SD = 0.63) and second half of the session (M = 1.44, SD = 1.02), $t(12) = -0.87$, $p = 0.40$, and there was no significant difference between the number of steps where errors occurred (M = 0.60, SD = 0.24, M = 0.53, SD = 0.26), $t(12) = 1.48$, $p = 0.17$. In the conceptual condition, there was a significant decrease in the total number of errors that were made between the first (M = 3.46, SD = 2.84) and the second half (M = 1.69, SD = 0.96), $t(12) = 2.36$, $p < 0.05$ and there was also a significant decrease in the number of steps where an error occurred (M = 0.72, SD = 0.15; M = 0.58, SD = 0.17), $t(12) = 2.45$, $p < 0.05$. Thus, in the conceptual condition, we see a decrease from the first to the second half in both interactive talk and problem-solving errors.

To better understand this relationship, we computed two Pearson's correlations. Outliers were removed based on being more than 3 standard deviations away from the mean. First, we analyzed the relationship between the change in interactive talk and the change in the number of steps with errors. There was a strong positive correlation between the change in interactive talk and the change in the steps with errors, $r(10) = 0.59$, $p < 0.05$. Thus, both interactive talk and the number of incorrect steps decreased over time and these decreases were strongly associated with each other. The second relationship that we analyzed was the correlation between the change in interactive talk and the change in total errors. There was a negative correlation between the change in interactive talk and the change in total errors with marginal statistical significance, $r(10) = -0.53$, $p = 0.07$. This result indicates that dyads with a greater decrease of interactive talk from the first to second half of the session had less of a decrease in the total errors made.

4 Discussion and Conclusion

Through our analysis we found that in the conceptual condition, students who had a greater decrease in the amount of interactive talk tended to have a smaller decrease in the number of errors that they made, but students who tended to have a greater decrease in the amount of interactive talk tended to have a greater decrease in the number of steps where errors occurred. These results indicate that interactive talk may not be necessary for students to correctly solve a problem, which is supported by the positive correlation of decreased interactive talk and decreased steps with errors, but in-

stead interactive talk may be a tool students can use when struggling. Interactive talk may not be so critical for correct problem-solving performance once students become more proficient, but it is helpful when students make errors. The negative correlation with the total errors would suggest other behaviors are occurring when students make multiple errors on the same step and where an area for future work. We did not find these same patterns for the procedural condition indicating that there may be different productive learning behaviors for procedural knowledge. The different results may indicate that for procedural knowledge there is less of a need for the deep understanding that is associated with interactive talk to overcome errors.

To be able to provide better support for learning through collaborative ITSs, it is important to understand how the collaboration may change as students work together. Although interactive talk is often held as the gold standard in collaboration [2], our results suggest that interactive talk may not be necessary for the entire duration of a collaborative session, but only when errors occur. It would follow that a decrease in interactive talk over time is not necessarily an indication that the quality of the collaboration is deteriorating. Rather, it may signal that the interactive talk is invoked in an adaptive manner, specifically to deal with impasses. By analyzing the change in collaborative dialogue over the course of a lesson, we were able to clarify how interactive talk and in-tutor learning relate to each other. By analyzing shorter time intervals than halves for future work, we may be able to build upon our findings presented in this paper and discern smaller patterns that may be present in the process data.

Acknowledgments. We thank the CTAT team, Daniel Belenky, and Amos Glenn, for their help. This work was supported by Graduate Training Grant # R305B090023 and by Award # R305A120734 both from the US Department of Education (IES).

5 References

1. Chen, G., Chiu, M. M., & Wang, Z.: Social metacognition and the creation of correct, new ideas: A statistical discourse analysis of online mathematics discussions. Computers in Human Behavior, 28(3), 868-880 (2012)
2. Chi, M.T.H.: Active-constructive-interactive: a conceptual framework for differentiating learning activities. Topics in Cognitive Science, 1, 73-105 (2009)
3. Mercer, N.: The seeds of time: Why classroom dialogue needs a temporal analysis. The Journal of the Learning Sciences, 17(1), 33-59 (2008)
4. Molenaar, I., & Chiu, M. M.: Dissecting sequences of regulation and cognition: statistical discourse analysis of primary school children's collaborative learning. Metacognition and learning, 1-24 (2014)
5. Olsen, J. K., Belenky, D. M., Aleven, V., & Rummel, N.: Using an intelligent tutoring system to support collaborative as well as individual learning. In 12th International Conference on Intelligent Tutoring Systems, 134-143 (2014)
6. Reimann, P.: Time is precious: Variable-and event-centred approaches to process analysis in CSCL research. International Journal of Computer-Supported Collaborative Learning, 4(3), 239-257 (2009)
7. Wise, A. F., & Chiu, M. M.: Analyzing temporal patterns of knowledge construction in a role-based online discussion. International Journal of Computer-Supported Collaborative Learning, 6(3), 445-470 (2011)