Investigating the Relationship between Dialogue Responsiveness and Learning in a Teachable Agent Environment

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Abstract. Using the Betty's Brain Teachable Agents learning environment, we explored a potential relationship between a student's responsiveness to pedagogical agent feedback and the student's learning and performance in the system. We found that both dialogue and action responsiveness metrics were significantly correlated with learning gains in pre- to post-tests, but only action responsiveness was significantly correlated with task performance scores. Dialogue responsiveness was also a better predictor of learning gain than were standardized test scores.

Keywords: learning environments, responsiveness, data collection

1 Introduction

In this paper, we examine a result from the Betty's Brain learning environment [1] to explore a potential relationship between *student responsiveness* and learning and performance metrics. We define student responsiveness to agents ('responsiveness') as the degree to which students are accepting of advice provided by the agents. In Betty's Brain, agents ask for permission before delivering feedback. For instance, an agent might say 'Excuse me, but you seem to be having trouble. Would you like some help?' Students who are not currently interested in advice can respond by clicking 'no' from a list of options and dismiss the feedback. When students instead click 'yes', they are considered to be 'responsive to dialogue' from the agent. Similarly, when students follow the advice of an agent, they are considered to be 'responsive by action' to the agent's advice.

We conducted a study in 7th grade science classrooms that shows a correlation between student responsiveness and learning gain. Additionally, the dialogue responsiveness was better correlated with learning gains than is a test of prior academic achievement. This result suggests that the responsiveness metrics may be used, in conjunction with other metrics, for more effective system adaptation to individual learners.

2 Classroom Study and Results

We have conducted several classroom studies where students use Betty's Brain to learn and gain a better understanding of a variety of science topics. In these

studies, the science content provided by Betty's Brain is closely linked to the school's science curriculum. At the beginning of each study, the science teacher introduces students to the topic during regular classroom instruction. The intervention phase starts with an overview of causal relations and concept maps during a 45-minute class period. This is followed by a hands-on training session with the system on the next day. Over the following 4-5 days, the students learn about the science topic use it to complete their learning task.

The Betty's Brain learning task implements the learning-by-teaching paradigm to help middle school students develop cognitive and metacognitive skills in science and mathematics domains [1, 2]. It features Betty, an agent that students teach, and Mr. Davis, an agent that mentors students as they teach. Students using Betty's Brain must read about a scientific topic and structure their newly-acquired knowledge in a causal concept map. Betty uses this concept map to answer questions and take quizzes, and students succeed in the learning task when they have successfully taught Betty everything she needs to know.

In the present study, we worked with 28 7th-grade students in middle Tennessee science classrooms. We have analyzed the data from this study to investigate three research questions: (1) Would more responsive students show greater learning gains? (2) Would more responsive students build more complete concept maps? (3) Is student responsiveness in Betty's Brain more predictive of learning gains and performance measures than standardized test scores?

Learning gains were assessed as the normalized learning gain on pre- and post-tests. The test included 18 multiple-choice questions on climate change and 16 multiple-choice questions on causal reasoning in general. Task performance was calculated based on the completeness and accuracy of each student's final concept map. We define a student's *map score* as the number of correct links minus the number of incorrect links in the student's final concept map.

More responsive students, we hypothesize, will score higher on our learning and performance measures described above. Additionally, if responsiveness strongly affects learning gains and task performance, we expect that it will predict these values at least as well as a student's prior academic achievement. We use student performance on the Tennessee Comprehensive Assessment Program (TCAP) standardized test as a measure of prior academic achievement. The results of this analysis are presented as correlations in Table 1.

	Normalized Learning Gain	Map Score
Dialogue Response	0.477*	0.149
Action Response	0.402*	0.431*
TCAP	0.245	0.405*

Table 1. Correlation (R) of Learning and Performance with Responsiveness and TCAP (* $p < 0.05$)

These results show that both metrics of responsiveness were more correlated with learning gain than were TCAP scores. Additionally, TCAP scores and action responsiveness were significantly correlated with map score, but dialogue responsiveness was not correlated with map score. One possible interpretation of these results is that TCAP scores are a better predictor of an ability to navigate an open-ended learning environment like Betty's Brain. Students better able to navigate such environments should achieve more success at building their maps. In addition, TCAP scores were not strongly correlated with learning, especially compared to responsiveness. This might indicate that students who were less adept at building concept maps were more willing to listen to advice to read and think carefully about the domain knowledge.

3 Conclusion

In this paper, we have presented results from a study that show the potential value of using student responsiveness metrics as predictors of student performance and learning. As we move forward in this line of work, we will expand our study to obtain stronger evidence supporting the validity of the responsiveness metrics.

If further verified, these metrics could provide easily-calculated indicators of student learning. When combined with other metrics, such as current performance, they could be used to help determine whether or not a student needs more advanced scaffolding or more directed feedback. This would allow us to develop more powerful, adaptive methods for helping unresponsive students reengage with the Betty's Brain learning task. We will explore these possibilities further as we continue our research.

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