The Effect of Scaffolding on the Immediate Transfer of Students' Data Interpretation Skills Within Science Topics

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Abstract: Cultivating science inquiry skills is increasingly seen as important to students' science literacy and effective scaffolding can support productive and successful inquiry practices. In this paper, we examine the evaluations of data interpretation practices of students who conducted inquiry within Inq-ITS, an intelligent tutoring system for science. We trace students' progress on data interpretation tasks to a new science topic after having received scaffolds that assist with the procedural aspects of data interpretation. Results show that, overall, after receiving data interpretation scaffolds within the system, students were more skilled at interpreting data in the new topic. However, there were still certain aspects of data interpretation with which students experienced difficulty after receiving the scaffolding.

Introduction

Developing explanations is a key inquiry practice in national science standards and is seen as essential for fostering students' science literacy (McNeill & Krajcik, 2011). Toulmin's (1958) model of argumentation identifies three aspects of explanation: the use of claims, evidence, and reasoning; others concur (Gotwals & Songer, 2009). Students often have difficulties with science argumentation practices, such as using appropriate and sufficient data and providing reasoning for their claims (McNeill & Krajcik, 2011). Other research has shown that students: may not link their data to their claims (Schunn & Anderson, 1999), change ideas about causality (Kuhn, Schauble, & Garcia-Mila, 1992), do not relate outcomes of experiments to the tested theories (Schunn & Anderson, 1999), and rely on theoretical arguments rather than evidence (Schunn & Anderson, 1999). These previous studies have used either verbal protocols or written responses to measure and address these difficulties, but, important to our work, have not lead to scalable support for inquiry practices requiring claims, evidence to support claims, and reasoning linking claims to evidence. Creating assessments of these skills is a critical yet challenging task (McNeill & Krajcik, 2011) because coding the types of data collected through verbal protocols and written responses is labor-intensive and requires the use of inquiry progressions and rubrics (e.g. Gotwals & Songer, 2009; McNeill & Krajcik, 2011). Supporting students in the development of this form of inquiry is also critical and challenging (Gotwals & Songer, 2009). The use of computer-based support may help facilitate this by automating the assessment and delivery of scaffolds, but there has been a lack of research examining either how these explanation practices can be assessed and supported or how computer-based scaffolding can help foster students' development of these skills over time (Windschitl, 2000).

The goal of this study is to use real-time scaffolding integrated into Inq-ITS, Inquiry Intelligent Tutoring System (Gobert et al., 2013b; inqits.org), to foster the development of the inquiry practices of data interpretation and warranting claims, which, to us, underlie argumentation practices necessary for communicating science findings. Secondly, we evaluate how well students can transfer these data interpretation practices to a new topic after receiving scaffolding via our pedagogical agent, Rex, a cartoon dinosaur. We address the question of whether scaffolding has a positive effect on data interpretation by looking at students' performance on a task in a new physical science topic immediately following scaffolding (Sao Pedro et al., 2012).

Transfer and scaffolding of inquiry skills

One way to provide support for the acquisition and transfer of inquiry practices is through the use of scaffolds. When students are having difficulty with inquiry, scaffolds can help them achieve the success they could not on their own (Kang, Thompson, & Windschitl, 2014; McNeill & Krajcik, 2011). Specifically, scaffolds that are developed to address specific aspects of scientific inquiry on a fine-grained level can help students receive the help they need and target the exact sub-skill on which they are having difficulty. Furthermore, scaffolding approaches that react in real-time within a computer environment can provide scalable guidance and support the development of inquiry skills by automatically detecting problems with inquiry (Sao Pedro et al., 2013; 2014), contributing to a deeper understanding of the content and inquiry processes.

Inq-ITS

Inq-ITS is a web-based science environment that assesses and scaffolds middle school students' inquiry skills (NRC, 2011) in real time as they experiment with interactive simulations for Physical, Life, and Earth Science. Within each activity, students conduct inquiry by articulating a testable hypothesis, "experimenting" by collecting data, and interpreting data. In this paper, we focus on inquiry activities for two Physical Science topics: Density and Free Fall. The activities in the Density microworld aim to foster understanding about the density of different liquid substances (water, oil, and alcohol). The activities in the Free Fall microworld aim to foster understanding about the relationship between a ball's mass, initial and final kinetic and potential energy, or its final speed and acceleration, when it is dropped from different heights.

A key aspect of the system is its capacity to provide an assessment of students' inquiry practices based on the processes a student follows and the work products created. The system uses knowledge-engineered and data-mined rules to evaluate log files generated from student interactions within the microworlds as a measure of student performance. Inq-ITS has been shown to be an effective method for assessing inquiry skills in authentic scenarios (Gobert et al., 2013b). For data interpretation, these assessed skills are:

- Selecting correct IV for claim
- Selecting correct DV for claim
- Correctly interpreting the IV/DV relationship
- Correctly interpreting the hypothesis/claim relationship
- Warranting with controlled trials
- Correctly warranting the IV/DV relationship
- Warranting the claim with more than one trial
- Correctly warranting the hypothesis/claim relationship

Inq-ITS can also deliver scaffolds to students in real time via a pedagogical agent. Prior work in Inq-ITS (Sao Pedro et al., 2013; 2014) has shown that scaffolding can help students both acquire and transfer two data collection practices that students did not know at the onset of the study. The data interpretation scaffolds used in Inq-ITS are designed to address four categories of procedurally-oriented difficulties that hone in on the sub-skills underlying data interpretation to provide targeted support for students' specific difficulties (Moussavi et al., 2015). These data interpretation scaffolding categories are: (1) The claim IV/DV does not match the hypothesis IV/DV; (2) The trials selected for warranting are not properly controlled; (3) The claim does not reflect the data selected; and (4) The claim is incorrect as to whether it supports/ does not support the hypothesis.

Methodology

Data was collected over the course of students' interactions in two virtual labs in Inq-ITS.

Participants

Data was collected from 23 8th grade students from the same school in Massachusetts. All the students had previously used Inq-ITS, but not with its scaffolding component.

Procedure

Topic 1: Density

Students completed the density activities in their science classroom after the content had already been introduced in the class. There were three activities. The first activity had no scaffolding support so as to record baseline data of students' inquiry practices. For the next two activities, students received scaffolding support in hypothesizing, data collection, and data interpretation. While the focus here is on the data interpretation scaffolding, it was important that students be scaffolded throughout the inquiry process because students must have a testable hypothesis and have collected appropriate data before they can try to correctly analyze the data and create a claim.

Topic 2: Free fall

This set of activities took place three weeks after the activities in topic 1. Students completed the free fall activities in their science classroom. Students had not yet learned about the content presented in these activities and as such, these activities served as a sort of content pre-test. No scaffolding support was present for any student throughout these activities.

Data analysis

The skill evaluations generated from the assessments within Inq-ITS (as described above) were examined for immediate skill transfer (Sao Pedro et al., 2012). To analyze transfer, we first looked at students' *first chance* to demonstrate the various data analysis practices in the second topic (Free Fall). This allows us to get an initial look at the students who received data interpretation scaffolding in the first topic to see if it had a positive impact on the transfer of data interpretation practices across topics. If scaffolding had a positive impact on data interpretation skills, we would expect to see more students demonstrating the skills correctly in the second topic than in the first.

Findings

Results from this analysis (see Table 1) showed that for 6 out of 8 of the data interpretation skills evaluated, at least 50% of the students demonstrated the skill correctly on their first try in topic 2. The three skills that the highest percentage of students demonstrated correctly on their first try in topic 2 were: selecting the correct DV for the claim, selecting the correct IV for the claim, and warranting the claim with more than one trial. The two skills that less than 50% of the students demonstrated correctly on their first try in topic 2 were: correctly interpreting and correctly warranting the claim/hypothesis relationship.

Table 1: Students' progress in topic 2

	Students demonstrating skill correctly in topic 2		**Students demonstrating skill correctly in topic 2 after demonstrating incorrectly in topic 1**		
Evaluated Data Interpretation Skill	**# of students (out of 23)**	**% of students**	**# of students incorrect in Topic 1**	**Number of students that got skill correct in Topic 2**	**% of students**
Interpreting the IV/DV relationship	12	52.17%	14	6	42.86%
Selecting correct DV for claim	21	91.3%	8	7	87.5%
Selecting correct IV for claim	20	87%	2	1	50%
Interpreting the hypothesis/claim relationship	10	43.48%	15	6	40%
Warranting with controlled trials	13	56.52%	10	2	20%
Warranting the IV/DV relationship	12	52.17%	14	5	35.71%
Warranting the claim with more than one trial	20	87%	6	3	50%
Warranting the hypothesis/claim relationship	10	43.48%	15	5	33.33%

To get a closer look at how scaffolding is affecting the transfer of skills, we took a second look at the data, this time using only students who did not correctly demonstrate the skill on their first try in topic 1. This will ensure that we do not include students who may have already known the skill prior to using the microworlds and instead focus on the students who are acquiring the skill through the support of the scaffolds. These results showed that some degree of acquisition and transfer of skill was evident for all data interpretation skills. The three skills that the highest percentage of students demonstrated correctly on their first try in topic 2 were: selecting the correct DV for the claim, selecting the correct IV for the claim, and warranting the claim with more than one trial. The two skills that the lowest percentage of students demonstrated correctly on their first try in topic 2 were: warranting with controlled trials and correctly warranting the claim/hypothesis relationship.

Conclusion and implications

Our findings showed that, after scaffolding, students were better able to create a claim (focusing on the appropriate IV/DV) and choose more than one piece of evidence to warrant their claim, two previously documented areas of difficulty for students (McNeil & Krajcik, 2011; Schunn & Anderson, 1999). This suggests that our targeted scaffolding, which provides real time help when students need it, can help students with difficult practices underlying explanation.

Our findings also showed that students continued to struggle in the new topic with warranting claims with controlled trials and correctly interpreting/warranting the claim/hypothesis relationship. The difficulty with warranting claims with controlled trials may be linked to another known difficulty students have with science inquiry – collecting data with controlled trials (Sao Pedro et al., 2012) and may therefore be a more persistent difficulty needing more scaffolding support. The student behavior surrounding the difficulty with interpreting and warranting the claim/hypothesis relationship is less clear, as not much research has been conducted on this particular skill. While students may be asked to provide a rebuttal of a different claim (with qualifying evidence and reasoning) once they have made their own claim (e.g. McNeill & Krajcik, 2011), students are rarely asked to definitively give a statement about whether or not their claim supports or refutes their original hypothesis. Further research is needed to address why students have difficulty with this, but it is possible that the acquisition of this skill is impeded by students experiencing confirmation bias and having a disinclination to abandon a favored hypothesis despite having interpreted their evidence to come up with a different claim (Klayman, 1995).

Conceptualizing and supporting the components of the explanation framework – claim, evidence, and reasoning – in an automated and fine-grained way with appropriate sub-skills can help us unpack and target known difficulties documented by previous research (Gotwals & Songer, 2009; McNeill & Krajcik, 2011; Schunn & Anderson, 1999). This work shows that scaffolding these data interpretation practices in real-time can be a beneficial way to aid students in both acquiring and transferring these skills to new science topics, even when students may not have initial content knowledge in that topic. This work also shows that students can have persistent difficulty with regard to classifying the relationship between a claim and a hypothesis (i.e. saying if the claim supports or refutes an initial hypothesis), suggesting that this skill may be more difficult for students to acquire and transfer and may, therefore, need more scaffolding support.

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