Taking Up the Mantle of Knowing: Supporting Student Engagement in Progressive Scientific Discourse in Geoscience

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Abstract: Learning science involves students engaging in disciplinary discourses. In this case study, middle school earth science students were led through an online module designed to support exploration of plate tectonics through the use of interactive data visualization and simulation tools. This study investigates how teacher questioning, curricular features, or other student's talk scaffold progressive discourse. Preliminarily findings revealed that students' participation in progressive discourse is predicated on teacher-supported sensemaking and a learning environment that scaffolds student questioning and exploration.

Introduction

The Next Generation Science Standards (NGSS) have shifted the focus of science education to consider disciplinary core ideas, cross cutting concepts, and scientific and engineering practices, placing a clear emphasis on student explanatory talk (NGSS Lead States, 2013). The intent was for students to be engaged in authentic scientific practices that approximate those enacted by the various scientific disciplines. Given the importance of and emphasis on creating discourse-based science learning communities, having a better understanding of how best to scaffold the creation of these communities is essential. While there has been a great deal of study of classroom science discourse around argumentation (e.g. Berland & McNeill, 2010), this represents only a small part of the discourse that forms the backbone of science communities and in particular overlooks the notion of sense-making as a critical form of science talk (McDonald & Kelly, 2012). Science as a discourse practice is multifaceted and complex and students will move in and out of different kinds of discourse as they engage in science practices. Science learning environments need to be designed to support a general trend in student talk toward more sophisticated and productive forms. To do that we need to better understand the complexity of science learning environments and the ways they scaffold productive student discourse.

Theoretical framework

Students learning science should be engaged in scientific practices, or science-in-the-making (Kelly, Chen, & Crawford, 1998). Students need to be positioned as knowledge builders and a primary goal of science education should be to cultivate students' epistemic agency (e.g. Miller et al., 2018), "students being positioned with, perceiving, and acting on, opportunities to shape the knowledge building work in their classroom community" (p. 1058). However, providing opportunities for students to leverage their epistemic agency does not happen on its own, and learning environments must be designed to create space for students. Developing students' epistemic agency requires careful scaffolding across the elements of the learning environment including the tasks students are engaged in, the tools they use, and the talk they use to accomplish this (Sohmer, Michaels, Connor, & Resnick, 2009). In addition, a teacher needs to orchestrate pedagogies responsive to students' ideas and use student ideas as a foundation to build on, extend, and make their ideas more sophisticated and productive (Windschilt, Thompson, & Braaten, 2018). In other words, there needs to be support for the progress of the ideas of the classroom community toward better explanatory models of scientific phenomena.

Leaning on the idea of science as the progress of ideas, Bereiter (1994), in response to post-modern critics of science, characterized science not as a search for truth, but in terms of progressive discourse. Science is fundamentally social and therefore, "people with opposing views can engage in discourse that leads to a new understanding that everyone involved agrees is superior to their own previous understanding" (p. 6) and that science should be committed to "progress itself" (p. 7). Designing learning environments to cultivate epistemic agency requires repositioning science as progressively more productive ideas generated and tested by a community of inquiry where students are producers of knowledge. The goal of the community is not to have students remember the productive explanations from authorities, but to develop their own increasingly better explanations.

Bereiter’s (1994) progressive discourse is characterized by four key commitments: mutual understanding, empirical testability, expansion, and openness. And he argues a general adherence to these commitments defines science as a discipline. This type of discourse has the potential to support epistemic agency for students because it is not focused on being individually and canonically “right,” but grounded in the community deciding what ideas, evidence, and activities are useful to understanding a problem or phenomenon. If we want students’ classroom science talk to resemble the authentic talk of scientists’ practice, then it must include not only argumentation, but sensemaking where students “get somewhere” (Grimes, McDonald, & van Kampen, 2018). Our study investigates the discourse of students engaged in investigating geoscience phenomena in the context of an online curriculum with two embedded tools – a visualization and a simulation – to support their investigations. Specifically, our research question is: how do various scaffolds of a learning environment support students in epistemically authentic talk grounded in the norms of progressive discourse?

Methods

This study is part of a larger project assessing the use of a digital curriculum, Geological models for Explorations Of Dynamic Earth (GEODE), meant to facilitate students’ learning of the foundational big idea in geosciences of plate tectonics. There was an extensive data set collected, but this study focuses on video and audio recording made of instruction in seven focal teachers’ classrooms across 2 different schools totaling 16 classes. Two video cameras captured the large class interactions and audio recorders were placed on student tables to collect small group discourse. Two student pairs in each class were recorded using both screen capture and web cameras allowing for analysis of pairs’ talk with their actions as they used the online curriculum and embedded tools. These pairs were selected by the teachers to represent students across achievement levels.

Using a case study approach (Dyson & Genishi, 2005), videos of students including computer screen capture as well as whole-class interactions were coded for instances of talk including progressive discourse and sensemaking. Additionally, videos were coded for instances that indicated the source of scaffolding during students talk: teacher questioning, specific aspects of the online modules or tools, or peers.

GEODE curriculum and tools

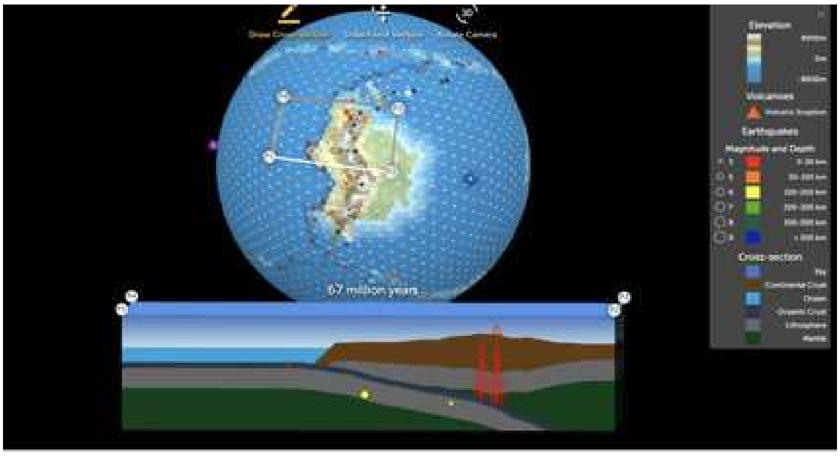

Figure 1. Tectonic Explorer.

The GEODE curriculum focused on the idea that Earth’s tectonic plates are in constant motion and interact in specific ways along their boundaries. The activities focus on a series of case studies of tectonic phenomena, builds on modeling literature, and is grounded in planning and discourses practices designed to support NGSS science and engineering practices. In the module, student’s investigate different areas of the Earth that represent key boundary interaction (convergent, divergent, and transform), and formulate hypotheses about causal mechanisms responsible for what is observed on Earth today. The case studies are structured to scaffold students investigating a phenomenon with data to develop their hypotheses which can be tested with a simulation modeling the plate tectonic interactions over time, called Tectonic Explorer.

Tectonic Explorer (TE; Figure 1) is a dynamic computational model-based simulation of an Earth-like planet where students can set parameters including relative plate densities, direction of plate motion, and locations of continents on plates. Then the physics engine of the simulator allows students to observe a global plate system, the interactions of plates along the boundaries, and resulting land formation, earthquake and volcanic eruptions.

Findings

Given the more structured nature online curriculum requires, asking sequential a priori questions to guide students' investigations, there were moments when students were focused on procedural question answering. However, we preliminarily characterize a continuum of science talk (see Figure 2) to capture the overall complexity of student talk. The continuum spans from procedural question answering, where students focused on providing the right answer to talk with identifiable practices of progressive discourse. Between the two extremes we saw sensemaking talk, where students used questions from the curriculum, the teacher, or a peer as a jumping off point to talk through science ideas, often drawing on the data representations or simulation tools in GEODE.

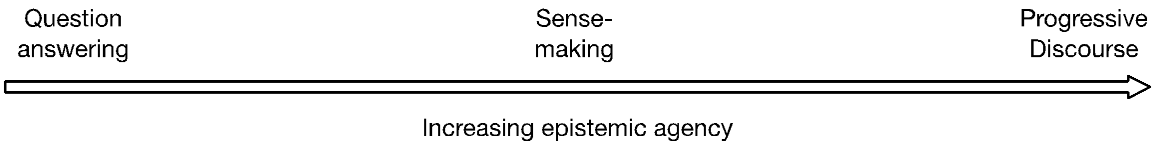

Figure 2. Discourse Continuum.

Our continuum reflects the variation and complexity of the discourse students engaged in and also represents the lack of clear boundaries between the kinds of discourse. These differences in student discourse can be seen as externalized manifestations of students taking up the mantle of knowers to varying degrees. Thus we can use this variety to make claims about the epistemic agency the students leveraged in learning new geoscience content.

The following transcript of student talk represents aspects of progressive discourse. The two students are working with TE to develop an explanation for the formation of island arcs – chains of islands that form where one tectonic plate is subducted beneath another creating volcanism and eventually islands; however, they are not yet trying to answer a specific question, rather they are interacting informally with the model.

Table 1: Transcript of students' progressive discourse

S2: Hey! Oh, that's interesting, it hasn't even collided yet and there's mountains forming	Expansion scaffolded by TE simulation tool which visualizes the formation of islands
S1: Yeah because the, uh, there's land under water that's rising up	
S2: That's pretty cool because its shoving the tectonic plate	
S1: Yeah	
S2: So that means…	
S1: Look at this, look at this right here	
S2: I know what that means, that means that this tectonic plate, it's denser than this one so this is probably 100% granite	Openness scaffolded by peer pressing on one anothers' ideas
S1: They're probably equal density and they're just pressing against each other like 2 pieces of paper they're going this (gesture: hands make triangle) way	
T: What evidence do you have for them having an equal density?	Empirical testability scaffolded by teacher questioning leading to mutual understanding between the students
S1: Uh, one of them isn't - oh wait! Um, wait, this one might have a lesser density because this one's going above it to form these mountain ranges.	
S2: If it went above wouldn't it have to have a lighter density	
T: Ok, so you're saying it has less density if it was going on top of the other plate	
S1: The plate, this one has more density so it's going down, this one has less density so it's going up	

In this section TE, the peer student, and the teacher respectively serve to scaffold student talk for different progressive discourse norms. In the first three lines, S2 names a new idea describing what they see in TE. S1 builds on this, indicating the norm of expansion. Next, S2 makes a causal claim about the density of the plate, however S1 critiques S2's claim, an indication of the norm of openness, because multiple ideas are positioned as possible explanations. Hearing this conversation, the teacher presses the students, specifically S1, to support their idea about equal densities with evidence, a clear move for the norm of empirical testability. While the students do not necessarily reach agreement, they are moving towards an agreed-upon claim, backed by evidence and reasoning, for the phenomenon they saw modeled in TE. What we see is the variety of scaffolds in the environment working in concert to support progressive discourse norms, and thus students' epistemic agency.

Conclusion

Students' authentic scientific talk is a critical area to understand given the increasing emphasis on science-as-practice (Kelly, Chen, & Crawford, 1998), and investigating student talk broadly allows a more complex conceptualization of disciplinary science discourses (McDonald & Kelly, 2012). We were able to see multiple components in the learning environment acting to scaffold the norms of progressive discourse and provide a context for students to leverage their epistemic agency (Miller, et al., 2018). While there have been characterizations of how to support authentic science practices in classrooms through planning and discourse (e.g. Ambitious Science Teaching, Windschitl, Thompson, & Braaten, 2018), that is only on aspect of the learning environment that proved critical to supporting students. In order to achieve progressive discourse as a set of norms in the classroom, students do require responsive support from a teacher to help them make sense of the data/evidence which they are engaging with toward explaining the target phenomenon; However, we found that neither teacher scaffolding nor high quality curricular materials alone are not enough to support students' authentic exploration. The entire learning environment contributes to a focus on phenomenon, including data visualizations and simulations and establishing norms for peer and teacher talk. We also saw that students cycle across the continuum between sensemaking and progressive discourse as they work through parts of the curriculum, indicating working through science ideas and setting norms for that work are in constant negotiation. Further analysis will help us determine the way distributed scaffolding (Tabak, 2004) provided by GEODE, the teacher, and peers contributes to opportunities for students to leverage their epistemic agency.

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