Supporting Teachers for Expansive Sense-Making in Elementary Science Classrooms

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Abstract: Reorganizing science learning towards expansive sense-making in elementary classroom settings will likely require disrupting long-standing narratives of schooling and science where taken-for-granted norms and practices structure marginalization and privilege. Supporting expansive sense-making, increased epistemic agency and authority, and more meaningful, consequential learning has proven elusive in elementary classrooms. Why is this the case? What can be done? This paper presents themes derived from analysis of multiple elementary science classroom video cases to hypothesize how sense-making shifts happen, albeit briefly, in a variety of classroom contexts and situations. Observing patterns in sense-making shifts enables us to confront how deep historical and cultural legacies of the grammar of schooling may inhibit shifts toward sense-making in science classrooms. These hypotheses raise implications for teacher education and for organizing schools to foster sense-making goals to support expansive and transformative science learning experiences.

Keywords: Elementary Science Teaching, Sense-making, Elementary Teacher Education, Equity

Why is expansive sense-making rare in elementary school science?

Although the science education community has consistently encouraged movement away from emphasizing the acquisition of facts, skills, and technical language, this shift has proven challenging to make in practice (e.g., Bang, et al., 2017). Teachers are often concerned when students' ways of explaining science events diverge too far from canonical science and fear that de-emphasizing technical vocabulary, formal science writing, and mathematical precision shortchanges students' academic progress in the long run. Real transformation will likely require disrupting and desettling long-standing narratives of schooling and science where taken-for-granted norms and practices structure marginalization and privilege (e.g., Miller, et al., 2018). These grammars of schooling and, particularly, of school science are deeply entrenched as historical and institutional legacies infused through teachers' work, tools, and tacit expectations for science education. Therefore, calls for fundamental changes in science education present a daunting challenge of shifting the daily pedagogical work of organizing learning (Tyack & Cuban, 1995).

Our long-term goal is to develop stronger theories about teachers' pedagogies within the historical and cultural context of school science so that we can design more powerful pedagogical tools to make science education more meaningful for students. We examine how teaching can and cannot help shift toward expansive and potentially transformative sense-making in schools. We examine teaching and learning interactions in elementary science classrooms to describe moments when the sense-making narrative shifts to position learners as sense-makers and moments of stasis when classroom science interactions position students not as sense-makers but as knowledge-acquirers. Specifically, we pursue the following research questions: 1) How do teaching and learning interactions in elementary science classrooms position students as sense-makers? 2) How do positions as sense-makers move in relation to broader narratives of science in schools?

We present themes from across multiple video cases to hypothesize how and why sense-making shifts happen, often only fleetingly, in a variety of classroom contexts and situations. Observing patterns in how and when sense-making shifts occur enables us to confront how deep historical and cultural legacies of the grammar of schooling may be at odds with a shift toward sense-making in science classrooms presenting teachers with paradoxes and barriers that may limit efforts to shift how science teaching and learning unfolds in practice. These hypotheses raise implications for initial teacher preparation, for on-going teacher professional learning, and for advising school leaders and policymakers about organizing schools to foster sense-making goals to support expansive and transformative science learning experiences.

Positioning students as sense-makers

A central challenge underlying a shift toward expansive and transformative science education involves helping teachers re-position themselves and their students as **sense-makers**. We define sense-making as working together to build and refine explanations that help learners figure out something puzzling (Odden & Russ, 2018). Sense-making happens as people forge connections between ideas, while simultaneously acknowledging and grappling with disjunctures. By checking one idea with another, people connect everyday and disciplinary language and experiences. As such, sense-making is iterative, dialogic, and dynamic occurring through cycles of construction and critique as possible explanations and problem-solutions are put into conversation to refine understanding over time.

A focus on the activity systems where learning takes place offers a dynamic view of sense-making as a joint accomplishment where learning is expansive. **Expansive learning** experiences involve movement of sense-making resources within activity systems and leads to the creation of shared knowledge and practices (e.g. Gutiérrez, 2008). System changes trigger shifts in power and control often creating structural tension. To understand how teachers and students engage in potential expansive learning experiences, we draw upon Harré and colleagues' (2009) positioning theory. Positioning theory helps us analyze how teachers' and students' interactions work together to create a dynamic learning environment that, at least in theory, can shift from enacting subtractive forms of school science to fostering more expansive forms. As with other structure-agency dialectics, we use positioning theory to help make participation and narratives more visible so that we can seek out cracks and fissures to gradually make a change in how systems work.

Methodology

This multiple case study draws from three classroom video data sets of elementary science teaching. Two data sets come from publicly available classroom video examples shared on websites frequently accessed by science education researchers and teachers alike: 1) TERC's Inquiry Project (https://inquiryproject.terc.edu/index.html), and 2) the Responsive Science Teaching project (https://as.tufts.edu/education/responsiveteachinginscience/). We assembled the third classroom video data set as part of a larger study examining how elementary teachers learn to notice and respond to students' sense-making in science (e.g., Haverly, Calabrese Barton, Schwarz, & Braaten, 2020; Schwarz, Braaten, Haverly, de los Santos, under review). Taken together, these three sets of classroom video data offer multiple cases of elementary science teaching in a variety of different classrooms from a variety of different school, district, and state contexts across the U.S.

Analysis began by viewing the video segments in their entirety to get a general sense of the teaching and learning interactions included in each of the videos. After viewing and discussing classroom video samples, we began in-depth analysis by identifying episodes of science sense-making in each of the videos. The first round of coding used an open coding approach (e.g., Charmaz, 2006). Codes described actions and events seen in video segments (i.e., working in pairs, wondering about rocks) and identified interactions between teachers and students (i.e., giving student the floor, asking for student's idea). These codes sparked conversations within our research team. From these discussions, we generated a focused set of codes that were more abstracted from the data. Focused codes included codes drawn from concepts important in positioning theory and studies of epistemic agency and authority. This helped us identify how positioning students as sense-makers happens in moments of movement toward more expansive forms of sense-making characterized by public recognitions of agency and authority signaling genuine reciprocity between speaking and listening.

Findings

Across video cases, two collections of pedagogical activities had consequences for positioning students as contributors to sense-making in elementary science. First, pedagogical activities that **orchestrate student contributions for sense-making** are essential in shifting toward expansive science learning experiences**.** Fruitful orchestration involved: 1) teachers or students *making space* for students to offer contributions; 2) teachers or students *making sense* of students' contributions, and 3) teachers or students *making use* of students' contributions publicly.

For example, Mr. Matt, a 5th grade teacher, made space for a student's unexpected contributions and genuinely listened and reciprocated to make sense of students' contributions. While investigating force and motion, Mr. Matt asked students to present different car designs that might make a difference for the safety and motion of the car. Sierra contributed a novel idea that car length could be the most important safety feature. Mr. Matt and Sierra had the following exchange in which he explicitly expressed interest, showed curiosity, and made space for her novel contribution:

Mr. Matt:	Tell me about length, Sierra, I'm curious. Why is, in your mind, why is length the most important feature for safety?
Sierra:	Can I go up there? [Sierra is pointing to the document camera at the front.]
Mr. Matt:	No, you can just tell me from there. Or, do you have a drawing or something?

Sierra:	Well, it's the drawing that we kind of did.
Mr. Matt:	Oh, ok. You wanna put it up on the [document camera]? Yeah, go ahead.

Sierra began to explain her claim that the length of the car is the most important design feature to consider when gauging the safety of the car in a crash. Mr. Matt asked questions and used revoicing strategies to make sense of Sierra's ideas publicly so that all students could benefit from Sierra's contribution. Mr. Matt persisted in publicly working to clarify whether Sierra was thinking about car design preventing or responding in a crash. Making space for student contributions, followed by deliberate work to make sense of those contributions, allowed Mr. Matt to orchestrate a science sense-making narrative composed of canonical ideas about force, motion, and automotive design alongside students' ideas including surprises, like Sierra's. This positioned Sierra as a credible sense-maker whose contributions were worthy of attention in an effort to build knowledge collectively. However, cases did not always unfold this way, leading to a second collection of pedagogical activities.

After space is made for student contributions, a second collection of pedagogical activities govern how those contributions are positioned in relation to the on-going sense-making narrative that provides a throughline about purposes, practices, and priorities for making sense of science in a particular elementary learning experience. Coordinating student contributions in relation to a sense-making narrative consisted of three possibilities across the video cases: 1) eliciting, but not making sense or use of student contributions to compose the narrative; 2) collapsing student contributions into the authoritative school science narrative; and 3) improvising dynamically to compose a sense-making narrative with students as contributing authors just as Mr. Matt did with Sierra's contributions above. However, the first two possibilities proved to be far more common among episodes in the video cases.

For example, a 4th grade teacher, Ms. Candace, featured on TERC's Inquiry Project opens up a conversation with students about condensation visible on the outside of water bottles that have been frozen by asking "Where does that come from?" Students, having already pursued this line of sense-making in earlier learning experiences in Ms. Candace's classroom, contribute ideas tentatively claiming at first that the condensation comes "from the ice" but then modifying that idea to communicate that ice is not "leading through bottle" and it is instead "drawing in cold air or water vapor to the outside of the bottle." Ms. Candace, aiming to move students forward to an activity of finding the mass of frozen water bottles to compare with liquid water bottles, makes a small but authoritative move to settle students' uncertainty and collapse their contributions into the science narrative that she, at least for now, is controlling. She takes a long turn of talk concluding the conversation by explicating where the condensation does and does not come from and settles uncertainty by saying "We all agreed on that. … Alright?"

In cases such as this one from Ms. Candace's classroom, students' contributions are often present because the teacher or another student has made space by inviting those contributions. While this may initially position students as sense-makers, it is the orchestration of the science sense-making narrative that may have consequences for engaging students in more expansive and perhaps transformative forms of sense-making. In Ms. Candace's efforts to pursue a specific learning activity – one that would generate data about conservation of mass – on a certain schedule and resulting in a certain understanding of properties of matter, norms and expectations of science in school may subtly steer Ms. Candace away from taking the time to make sense of students' uncertainty and to make use of their ideas in composing the classroom's sense-making narrative about matter. This may explain why moves toward sustaining expansive sense-making were short-lived as glimmers rather than persistent patterns of science learning experiences in elementary schools.

Conclusions and implications

Understanding glimmers of sense-making can help to inform other teachers and teacher educators interested in supporting what Hall and Jurow (2015) call *consequential learning* - learning that is "genuinely useful to people and is understood as a competent way of knowing" (p. 176). For example, a small pedagogical move of making space for students to contribute may be critically important for consequential learning. At first glance, this move seems unremarkable because it seems so obvious. But, we consistently find that this small act of making space proves to be one of the most consequential ways that teachers can expand learning experiences with students.

What happens after making space for student contributions highlights how teachers use actions, tools, and interactions to exert power legitimizing *and* de-legitimizing students' sense-making (Bang, et al., 2017). Positioning students as sense-makers requires shifting epistemic agency and authority within classrooms, which has proven elusive (Miller, et al., 2018). Clinging to stereotypical portrayals of science has obscured legitimate ways that children make sense of science marginalizing some children while privileging others. Furthermore, the subtractive learning environment of many science classrooms is often reified in authoritative curriculum, assessments, and, sometimes, in an authoritative teacher such that it becomes a type of grammar of science in schools that resists change. These deep structures of schooling that shape teachers pedagogical activities may explain why sense-making is curtailed in elementary science classrooms Movement toward more expansive and transformative science learning calls for a new grammar of science in schools and requires disruption of the deeply held status quo grammar already in place. Having more complete theories of how and why teachers attempt but also refrain from expansive sense-making can inform teacher education, tools, and strategies for building a new grammar of science in schools.

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