Journal of Teacher Education
1–17

DOI: 10.1177/0022487118800706
journals.sagepub.com/home/jte
SAGE

"Making Space": How Novice Teachers Create Opportunities for Equitable Sense-Making in Elementary Science

Christa Haverly[1], Angela Calabrese Barton[1], Christina V. Schwarz[1], and Melissa Braaten[2]

Abstract

Scholarly calls to reform science education for all students emphasize scientific sense-making. Despite the importance of sense-making, few strategies exist to help novice teachers learn to notice and respond equitably to students' scientific sense-making in elementary science. In this article, we report on a qualitative case study in which we investigated sense-making moments that occurred when novice teachers facilitated classroom discussions. Findings suggest that when novice teachers *made space* in class discussions for sense-making—for example, by trying different responses to clarify student ideas or waiting before responding to figure out next steps—this expanded opportunities for shared epistemic authority; however, novices did not often recognize these moments as productive for sense-making. Findings also suggest that novice teachers may benefit from support to help them develop their abilities to notice, interpret, and respond equitably to students' scientific sense-making in class discussions.

Keywords

elementary education, science education, science teacher education, equity

Introduction

Every year, thousands of novice elementary teachers join the workforce, replacing retiring teachers and filling gaps left by high levels of attrition (Carroll & Foster, 2010). These novices feel pressure to learn how to manage a classroom and cover curriculum for standardized tests (Kennedy, 2005). As a result, novices' teaching focuses on students' behavior rather than on supporting students' sense-making (Levin, Hammer, & Coffey, 2009; Liston, Whitcomb, & Borko, 2006). Contemporary reforms in science education emphasize sense-making—that is, a proactive engagement in understanding the world by generating, using, and extending scientific knowledge within communities of practice—for all students (National Research Council, 2012). However, supporting students' sense-making is challenging for teachers. This dilemma is well-documented in science education where maintaining authoritative control over subject matter clashes with creating genuine opportunities to construct understanding (e.g., Braaten & Sheth, 2017; Windschitl, 2002).

Teachers struggle to predict what students will share, to envision managing students' sharing, or leveraging student thinking for learning. This leads to uncertainty in the classroom, requiring increased improvisation where teachers act as guides for student learning while still allowing students to make choices about what and how to learn (Schoerning, Hand, Shelley, & Therrien, 2015). Enabling students to make choices also requires a more flexible understanding of the science content, a competence eluding many novices (Larkin, 2013).

Sense-making refers to "what" students are learning and students' "ways of understanding" the world (Rosebery & Warren, 2008). A sense-making perspective positions students as capable of asking and answering scientific questions to build knowledge and skills (Engle & Conant, 2002). In this article, we focus specifically on *equitable* sense-making, where classroom interactions—typically grounded in an epistemic stance privileging particular ways of knowing and talking—expand, thereby shifting historicized relations of power and position (Bang, Brown, Calabrese Barton, Rosebery, & Warren, 2017; Seiler, 2001; Tan, Calabrese Barton, Varley Gutiérrez, & Turner, 2012). Teaching science for equitable sense-making leverages students' ideas, experiences, and cultural resources while disrupting power structures. This kind of teaching requires pedagogical strategies,

[1]Michigan State University, East Lansing, USA
[2]University of Colorado Boulder, USA

Corresponding Author:
Christa Haverly, Michigan State University, 620 Farm Lane, 313 Erickson Hall, East Lansing, MI 48824, USA.
Email: haverlyc@msu.edu

or practices, for noticing and responding to students' contributions (similar to Windschitl, Thompson, Braaten, & Stroupe, 2012). Despite the importance of sense-making and well-known challenges facing novices, few approaches exist to help them learn to notice and respond equitably to students' sense-making.

This article investigates how novice teachers improvise while facilitating classroom discourse. We look closely at select moments where novice teachers notice and respond to students in classroom discussions. How novice teachers respond to students' scientific sense-making—especially when their sense-making deviates from the teacher's planned script—shapes students' opportunities to learn (Rosebery & Warren, 2008; Stroupe, 2014). We focus in particular on how novices' noticing and responding facilitates or constrains opportunities for equitable sense-making.

This article reports on two cases in which participants *made space* for students' scientific sense-making during class discussions and one case in which this did not occur. *Making space* builds on Hand (2012) who conceptualizes students *taking up space* as contributing to classroom discourse in ways that challenge normalized and hierarchical systems of marginalization. Whereas Hand focuses on the actions of students to take up space, in this article, we think of making space as an action of teachers which has both pedagogical and epistemological dimensions. For example, teachers make space pedagogically by inviting students' contributions to classroom discourse and epistemologically by valuing multiple ways of making sense of science.

We argue that making space is potentially promising for framing novice teacher practice to support students' equitable sense-making and shift epistemic authority in science classrooms. Our analysis also indicates new questions for teacher education. Novices who made space did not recognize students' contributions as sense-making; instead, teachers saw confusion, misconceptions, and mistakes. This dilemma is in line with research by Braaten and Sheth (2017) and others, and it suggests that further support is needed for novice teachers to learn to notice and respond to students in equitable ways. Ongoing efforts to systematically design and refine supports for novice teacher learning indicate that novices can learn to notice students' sense-making and respond in more equitable ways (e.g., Russ, 2018). Better understanding sense-making moments may help teacher educators support novice teachers.

Conceptual Framework

Noticing and Responding

Noticing is a key component of teaching characterized by recognizing, attending to, and reasoning about salient classroom events and interactions (van Es & Sherin, 2002, 2008, 2010). Identifying noteworthy events is integral to noticing (van Es & Sherin, 2002). After teachers notice such events, they interpret student thinking, and then respond by making pedagogical decisions for upcoming lessons or by interacting in the moment. Teacher noticing differs from everyday observations by prompting teachers to draw on their "professional vision in action"—or, their knowledge of pedagogy, learning, and classroom practice (Benedict-Chambers, 2016; Goodwin, 1994; Sherin, Russ, Sherin, & Colestock, 2008). Professional vision in action is not well understood partly because it is challenging to detect or measure and partly because few studies examine teacher practice at this grain size (Lampert, 2010; Sherin et al., 2008).

Noticing and responding to students' sense-making is a high-leverage teaching practice. High-leverage practices are practices which are essential for novice teachers to understand and enact for every student in the classroom to learn (Ball & Forzani, 2009). As with other high-leverage practices, noticing and responding can appear invisible to an outside observer. Yet, enacting this practice with expertise provides increased opportunities for students to engage in equitable sense-making. In addition, this practice is a necessary condition for the learning portrayed in the Next Generation Science Standards (NGSS Lead States, 2013), where teachers must recognize and leverage students' knowledge as part of the larger system of practices, norms, and values of a science classroom. To achieve the vision set forth by NGSS, teachers must pay particular attention to how and why students engage in discourses and practices that make up participation in science (Engle, 2012; Engle & Conant, 2002; Hogan, Nastasi, & Pressley, 1999).

Equitable Scientific Sense-Making

We are concerned, in particular, with finding ways to support teachers in promoting equitable scientific sense-making in the classroom. Similar to meaning-making (Wickman & Östman, 2002), sense-making is a process in which students co-construct their understanding of the world as they generate, use, and extend their ideas in the classroom (Maskiewicz & Winters, 2012; Warren, Ballenger, Ogonowski, Rosebery, & Hudicourt-Barnes, 2001). A primary way individuals learn is through interactions among people, text, tools, and other objects (Greeno, 2006; Kang, Windschitl, Stroupe, & Thompson, 2016). Sense-making moments comprise such interactions and can create more opportunities for individual students to interact in ways that allow them to move collective sense-making forward. Sense-making, therefore, is integral to student learning (e.g., Hammer, 1995; Maskiewicz & Winters, 2012; National Research Council, 2007, 2012).

We conceptualize *equitable* sense-making as a co-construction of knowledge incorporating students' epistemic resources—including language practices, discursive forms, and cultural practices (Nasir, Rosebery, Warren, & Lee, 2006)—not always traditionally legitimized in classroom spaces. For students to have opportunities for equitable sense-making, they need to be noticed and responded to in

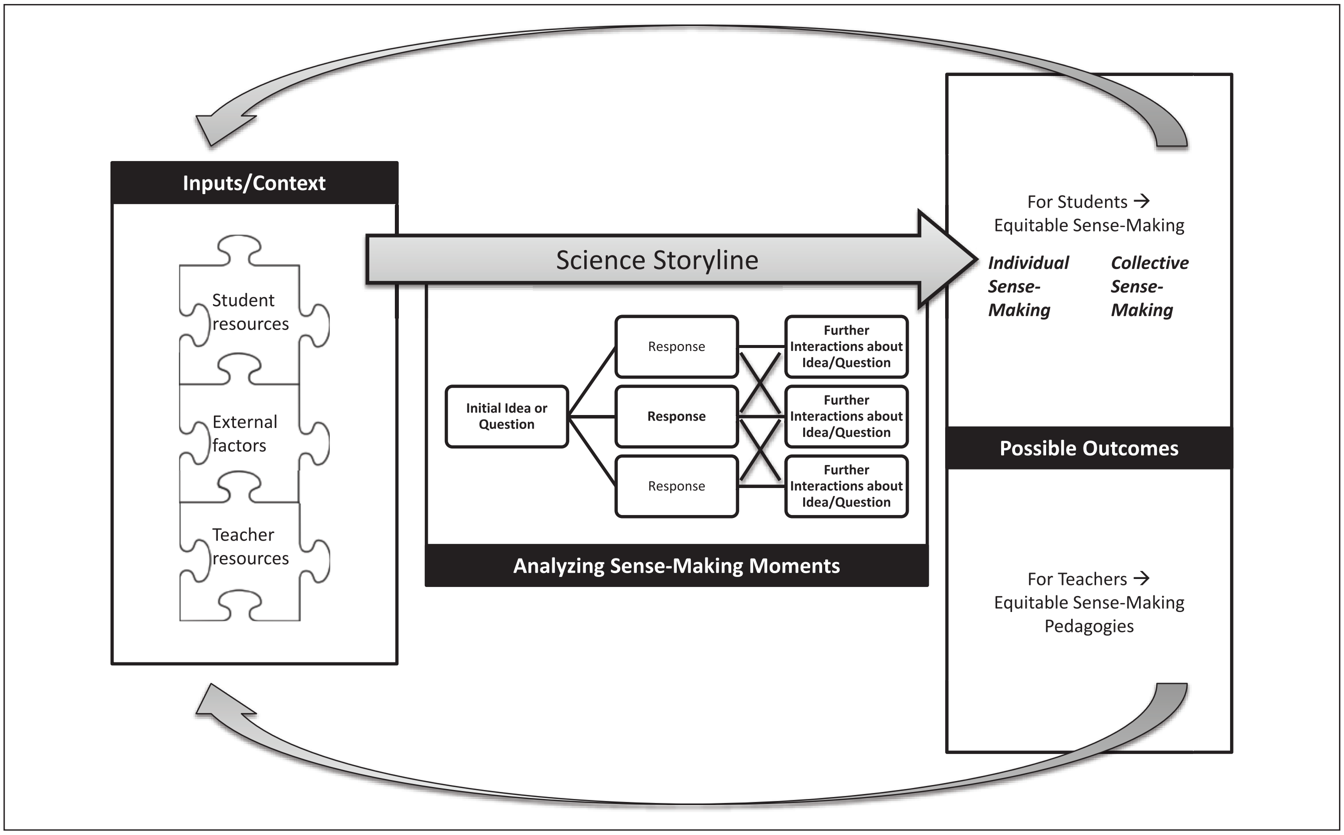

Figure 1. A model of sense-making moments.

ways that value and leverage their epistemic resources. Thus, we see shared epistemic authority as a key piece of equitable sense-making.

Epistemic Authority. Epistemic authority refers to whose knowledge and ways of thinking are positioned as expert in the science classroom (Engle, Langer-Osuna, & de Royston, 2014). Typically, epistemic authority rests in teachers and science texts (Forman & Ford, 2014). Calabrese Barton and Tan (2009) discuss how teachers and students can disrupt "settled hierarchies" by sharing epistemic authority (Rosebery, Warren, & Tucker-Raymond, 2015). In equitable science classrooms, peers and teachers view shared ideas as important epistemic resources which afford students epistemic authority (Engle & Conant, 2002).

In many science classrooms, students *contribute to classroom discourse but do not shift epistemic authority*. For example, teachers maintain epistemic authority when students' contributions show the teacher that they know "the" answer (Carlone, Haun-Frank, & Webb, 2011). In these cases, epistemic authority "organizes, sorts, and alienates students" (Carlone et al., 2011, p. 479), according to whose contributions to the classroom discourse count for constructing knowledge, rather than equitably sharing epistemic authority. However, when students' epistemic resources are leveraged by both the teacher and their peers within the classroom science community, students share epistemic authority contributing to knowledge construction while being accountable to peers and classroom scientific norms (Carlone et al., 2011; Stroupe, 2014).

In this article, we describe how particular moves made by novice teachers mediate equitable sense-making as teachers notice and respond to students' contributions while sharing epistemic authority with students.

A Conceptual Model of Sense-Making

Sense-making moments occur in a larger context. We speculate that these moments, when taken both individually and collectively over time, play a role in the larger context of sense-making and equity in a classroom. Figure 1 is a model of how we conceptualize noticing and responding to sense-making within a broader context. This model emerged throughout our analysis and has been useful for communicating our conceptual framing and findings.

The middle of the model depicts interactions comprising a sense-making moment. This begins with an *initial idea or question*—what the teacher or students do to set up the moment. Next, *responses*—what students and teachers say or do—happen as a result of the initiation. Finally, *further interactions about the idea or question*—ideas elevated to shared discourse, discussed privately, or tabled altogether—conclude the "moment." Throughout these interactions, teachers notice, interpret, and respond to students' contributions.

We consider any given sense-making moment to be bound by a particular idea anchoring students' sense-making. These interactions steer the *science storyline*. We conceptualize a science storyline as the scientific explanation for a given phenomenon that teachers want students to develop and ultimately understand. Science storylines could potentially be (a) teacher-constructed, where the teacher maintains epistemic authority, (b) co-constructed, where the teacher and students share epistemic authority, or (c) student-constructed, where epistemic authority shifts entirely to students.

On the right side of the model, we identify *possible outcomes* of sense-making moments. *Individual* students may develop deeper understandings of science as well as agency and authority to develop science storylines. *Collectively*, students' ideas become public resources for making sense of science, shifting collective agency and authority. *Teachers*, with support, may develop or refine pedagogies for facilitating equitable sense-making, furthering agency as reflective and equitable teachers.

On the left side of the model are *contextual* factors shaping how a given sense-making moment transpires. These factors include *student resources* (e.g., funds of knowledge, informal science experiences), *teacher resources* (e.g., content knowledge, beliefs, identity), and *external factors* (e.g., curriculum materials, school policies). Sense-making moments have multiple, interconnected instantiations over time resulting in a feedback loop that contributes back to the classroom culture and available resources. The arrows at the top and bottom represent how each moment fosters the next sense-making moment.

Research Questions

In this article, we focus on sense-making moments that occurred during science discussions and that highlighted possible equitable sense-making moves. These discussions took on various forms, but in each case, they served as the context for participation which established opportunities for sense-making. Our research questions focus on sense-making moments in these discussions:

- In what ways do novice teachers navigate sense-making moments in science discussions that result in equitable sense-making opportunities for students?
- What do novice teachers notice in these moments? How do they respond to student sense-making?

Method

Our exploratory study is grounded in qualitative case study (Yin, 2014). A case study design allowed us to closely examine interactions in moments of uncertainty between the novice teachers and their students while considering the impact of the teaching context.

Participants

The cases described in this article derive from a larger project examining noticing and responding practices from 15 teachers in the Midwestern United States, including eight intern teachers, one first-year teacher, and six experienced teachers (Schwarz, Braaten, Haverly, Calabrese Barton, & de los Santos, 2018). Throughout the article, we use pseudonyms to identify the participants and their students. Our intern participants were in their fifth year of a 5-year teacher preparation program at a Midwestern university. In this program, students take two science methods courses—one as a senior-level undergraduate course with a weekly field placement, and one master's-level course during their fifth-year full-time internship. Goals of these courses include learning how to plan and teach science lessons and units, establishing inclusive classroom communities that meet the needs of English language learners and differently abled students, developing an understanding of the nature of science, and reflecting on one's science teaching practice. At the time of data collection, these courses did not address sense-making, noticing, or epistemic authority. Instead, they addressed related topics including conducting and analyzing science talks with students and closely reflecting on students' scientific ideas. We recruited interns from their science methods class in the Spring semester. Four interns participated each year; we included all eight in the larger study.

This article features two interns (Paul and Melanie*) and a first-year teacher (Kendra). We selected these two interns' cases for this article as their practices illustrate two different approaches resulting in similar outcomes for students. We found the two cases not to be representative of the larger data set, but rather illustrative examples we wanted to unpack for further study and their potential implications for teacher preparation. We selected the first-year teacher's case as a counter-example in which her practice approximated that of the interns' but with different student outcomes.

Data Generation: Sense-Making Portfolios

With each participant, we generated a "sense-making portfolio" describing practices for noticing and responding to students' sense-making while teaching science. These portfolios consisted of several artifacts, including classroom videos, teacher interviews, and student work.

Classroom Videos. To characterize teaching practices, teachers video-recorded four science lessons, preferably in the same unit. Participating interns recorded lessons from their required science units for their science methods course. Their

*All names in this paper are pseudonyms.

science methods instructors focused coursework on preparing interns to actively engage students in shared experiences which supported their identification of patterns and construction of explanations (Sharma & Anderson, 2009).

Paul's case draws from his unit on the solar system. Two of the learning goals based on state standards were for students to recognize that gravity affects tides on Earth and the motion of planets and moons. In the excerpts used in this article, his students work through their ideas about gravity. Melanie's case draws from her unit on the states of water and the water cycle. One of Melanie's learning goals drawn from state standards was that students understand that clouds are not gaseous but are small drops of water. In the excerpts presented below, her students make sense of how a cloud forms. Kendra's case draws from her unit on evolution, and in the excerpt below, the class discusses the digestive systems of animals.

Interviews. We conducted semi-structured interviews with teachers after everyone—researchers and teachers—viewed the video-recorded lessons. Interviews captured teachers' reflections on noticing and responding to students' sense-making while viewing video clips together. Interview protocols, based on work by Kang and Anderson (2015), McLaughlin and Calabrese Barton (2013), and Thompson, Windschitl, and Braaten (2013), included questions about what teachers noticed about students' sense-making, how they interpreted students' responses and actions, and why teachers responded as they did.

Prior to the interviews, we asked participants to select 3 to 4 segments of video in which they felt like student sense-making was visible and to identify times where something interesting or surprising took place. Across the data set, we found that teachers selected segments where students were engaged in some form of discussion. While we also had videos of students engaged in investigations, writing in science notebooks, and learning outdoors, classroom discussions were highlighted during post-video teacher interviews presumably because teachers saw classroom discussions as spaces for students to make their sense-making visible.

In some interviews, the participants noticed some of the same moments that the researchers noticed when previewing the video. In others, researchers shared an additional moment they noticed to probe participants' thinking about what researchers were noticing. The cases presented in this article represent a combination of participant-selected and researcher-selected moments.

Analysis

Researchers analyzed data through multiple stages and levels of coding based on procedures for open coding and constant comparison (Corbin & Strauss, 2014). Our first pass involved watching the videos teachers shared in their portfolios and reading through interview transcripts. The goal of this initial read-through was to identify the following: (a) critical moments in student sense-making, or those moments where sense-making seemed to shift or disrupt the classroom discourse in a noticeable way (example codes: UNANTICIPATED, STUCK, SURPRISING), (b) how teachers talked about those moments (e.g., STUDENTS' RESOURCES, CLASSROOM RESOURCES, TEACHERS' RESOURCES), and (c) tensions and connections among teachers' anticipated science storylines and what actually happened during the episodes (e.g., CO-CONSTRUCTED, TEACHER-CONSTRUCTED, STUDENT-CONSTRUCTED, or FRACTURED). Examples of how we defined and refined these codes are included in Table 1.

During this round of data analysis, we noted links between coding categories such as times when teachers described being "stuck" in-the-moment as students said or did something they did not anticipate. These links between codes clarified meanings that teachers ascribed to these moments. The authors held weekly conversations on these insights as a way to work toward a consensus. Any differences in view were debated until new or refined codes were generated.

Our second pass involved identifying what we, the researchers, interpreted as the sense-making outcomes of these moments. In particular, with the help of our conceptual framework of equitable sense-making, we began to code for when these moments EXPANDED, MAINTAINED, or SHUT DOWN opportunities for students to advance sense-making. We used this axial phase of coding to uncover relationships between the students' sense-making, the teacher's actions and interpretations, and tensions emerging from the data. In developing these coding schemes, we paid attention to how and when epistemic authority for sense-making took shape in the classroom, and we paid attention to what this meant for the overall moment. As we began to make sense of patterns observed across cases, we redesigned the sense-making model (Figure 1). We used the sense-making model to diagram over a dozen individual cases, and as we did so, we continued revising and refining the model. The relationships and connections identified in this second stage of analysis, in turn, guided our selective coding and became categories and themes from which we selected our example cases for a final round of analysis and presentation.

Findings

Among the most salient concerns of novice teachers were moments when science lessons did not go as planned. Novices readily noticed when their students went "off-script" deviating from the teacher's anticipated science storyline. Responding to these off-script contributions presented a challenge for novices because it required them to work more flexibly with their science knowledge as well as with norms for participation (e.g., who participates, how, who has authority, why). When teachers made improvisational teaching decisions, the allowable science storyline sometimes

Table 1. Analyzing Moments of Science Sense-Making in Novice Teaching.

Component of sense-making model	Example codes	Definition	Example from participating teachers
Sense-Making Moments	UNANTICIPATED	Teacher indicates that they did not expect this moment; moment appears novel to teacher.	Student suggests state of matter where "particles are all together" before teacher introduces particles.
	STUCK	Teacher indicates that they were not sure what to do next; teacher appears unsure of what to do next.	Students bring teacher's attention to a discrepancy on PowerPoint slide versus students' graphic organizer.
	SURPRISING	Teacher expresses surprise at a student's contribution; teacher appears to be surprised.	Students located the fulcrum on compound levers that teacher did not know.
Contextual Resources	STUDENTS' RESOURCES	Cultural repertoires of practices and experiences students bring to school to make sense of science.	Student uses mom's recent experiences in car accidents to reason about what makes a car safe.
	CLASSROOM RESOURCES	Availability of materials, time, and institutional support for teaching science.	Competing pressures to extend mentor's science lessons versus transitioning to intern's lessons.
	TEACHERS' RESOURCES	Teacher's content knowledge, professional orientations, identities, pedagogical skill set, etc.	Teacher's confidence in her knowledge of science teaching despite lack of experience.
Science Storylines	CO-CONSTRUCTED	Teacher and students construct science storyline together sharing epistemic authority.	Teacher prompts students to talk and respond to one another as part of classroom routine.
	TEACHER-CONSTRUCTED	Teacher maintains epistemic authority and attempts to transmit knowledge to students.	Teacher tables a student's idea by writing it to the side on the board and not returning to it.
	STUDENT-CONSTRUCTED	Students have full epistemic authority for constructing science storyline.	Teacher, unsure of what to do next, allows students to talk through their ideas.
	FRACTURED	A science storyline which is cut off prematurely.	Teacher begins to entertain a student's question, but abruptly ends the discussion to move on.

expanded, fostering more robust opportunities for students to engage in sense-making. These improvisational decisions did not always appear to be intended as a means to share epistemic authority. Yet, as a result of making space, we noticed shifts in students' epistemic authority in the classroom allowing their ideas to become public resources for collective sense-making.

In what follows, we present three cases that expand upon these main claims. We selected the first two cases from Paul and Melanie because they each illustrate a different variation in the making space pattern we observed. A third case is offered as a brief counter-example of a moment in which Kendra made space for a student contribution, but it did not result in an equitable sense-making outcome.

Case 1: Try and See

In this first case, we explore how Paul made space for student sense-making by trying different strategies for hearing student voices to see what would happen next in the science classroom. Paul was a White male intern in a fifth-grade classroom that was predominantly White (~60%) with several English language learners in a college town in the Midwest. Paul valued helping his students to learn how to engage in a "positive discussion" by actively listening and responding to one another respectfully. In his interview, he stated,

> If you can teach a kid to have a positive discussion and not like point fingers and blame and yell and be able to have a discussion, everything else is so much easier, and you have developed that, the person, not the student but them as a person.

Paul was interested in developing the whole person, and he saw teaching students to communicate respectfully with one another as one way of doing this.

As an intern, Paul's strategies seemed unpolished—at times he lacked confidence in deciding his next move. Allowing students to share their ideas and figuring out how to respond can be difficult. Although Paul's moves showed a commitment to student voice, he was still figuring out how to enact this vision. He tried several different moves throughout his recorded lessons to make space for student voices. A common thread through Paul's science teaching is a *try and see* approach as Paul tried different strategies to see what might work to support his students' sense-making.

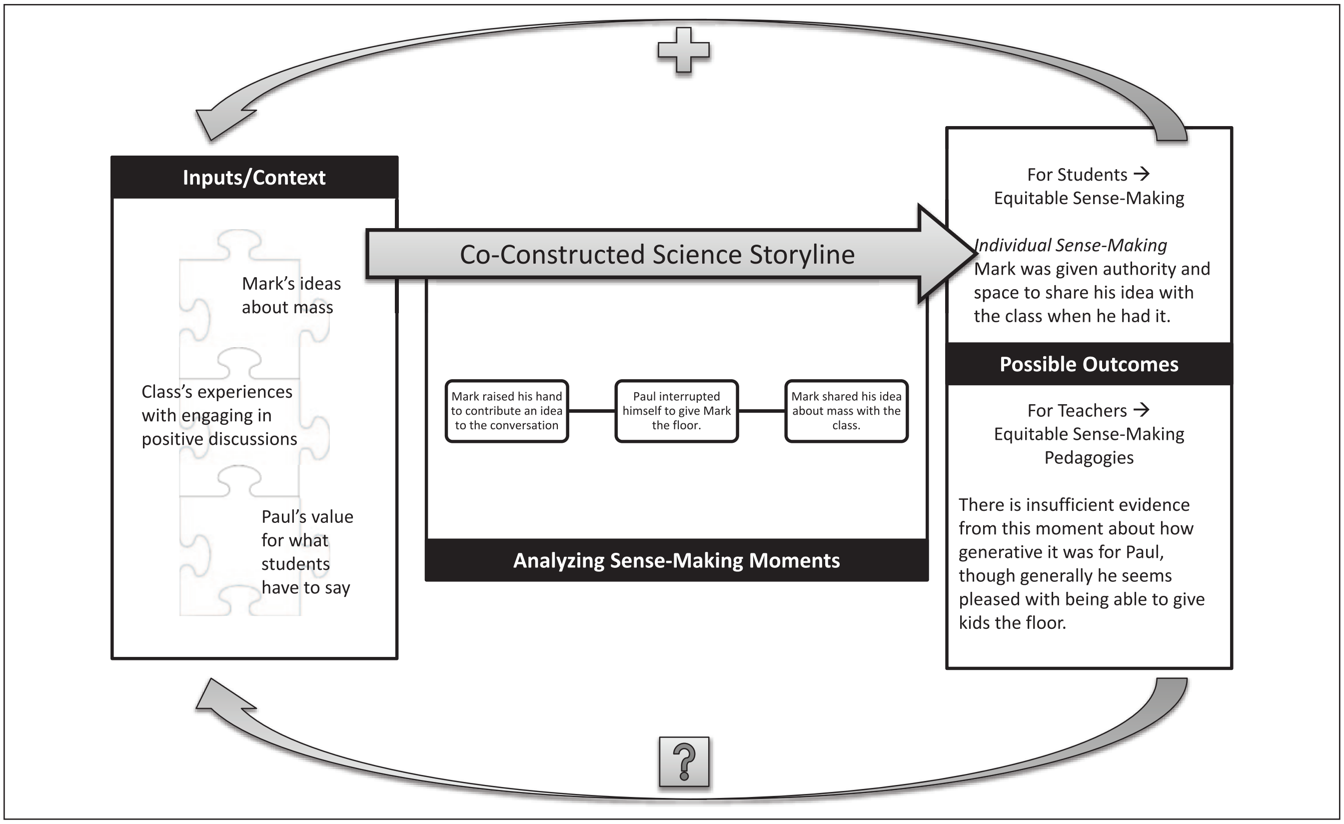

Figure 2. A model of Paul's strategy of giving students the floor.

Below, we present three vignettes to illustrate sets of moves Paul tried which made space for student sense-making. In each vignette, Paul made small moves that shifted some epistemic authority from himself to his students. Although this likely did not result in equitable sense-making to the fullest or most ideal extent, it does point to small moves novices could learn to move toward equitable sense-making as they refine their practice.

Giving Students the Floor. On several occasions during science teaching, Paul was responding to a student, and then he stopped mid-sentence to call on another student. We see this as an example of Paul making space in the lesson for students to talk. For example, take this exchange:

Paul: But I wanna focus on mass. Cuz density is a little bit different, uh, than mass. So, let's go back to Sarah's, uh, definition of mass, which is?
Sarah: Mass is something that's there.
Paul: Something that's there. So, there is a difference- Yes, Mark.
Mark: Uh, I think that maybe mass cuz you say mass is . . .

Paul was in the middle of processing what Sarah said; he began by repeating her definition, "something that's there," and he was about to do something with it: "so, there is a difference-." However, it's not clear if he was going to push back on her idea, connect it to other ideas that students had shared, clarify her idea, or something else because he interrupted himself to call on Mark and to hear Mark's ideas. He gave Mark the floor.

From his interview, we have some insight into why Paul sometimes used this strategy. He talked about it directly, although in reference to Geraldo, an English language learner student, who rarely participated: "I stop whatever's in my head and like 'go ahead you have an idea.'" Paul reacted to Mark's contribution in the same way as Geraldo's. He stopped what was "in his head" to let Mark share his idea (see Figure 2). This was a strategy that Paul used to elevate students' ideas in the class discussions and allow them to claim voice.

Paul's use of this strategy of giving students the floor provided opportunities for students to share ideas as Paul relinquished some epistemic authority. Paul interrupted his planned science storyline to make space for students to participate resulting in shared epistemic authority and a co-constructed science storyline. This was a risky move for Paul given that he did not know what the student would say or how that might shift the science storyline. The next two try-and-see strategies are less risky allowing Paul to adhere to his science storyline.

Highlighting Students' Ideas. Paul sometimes highlighted students' answers that aligned with his science storyline. In

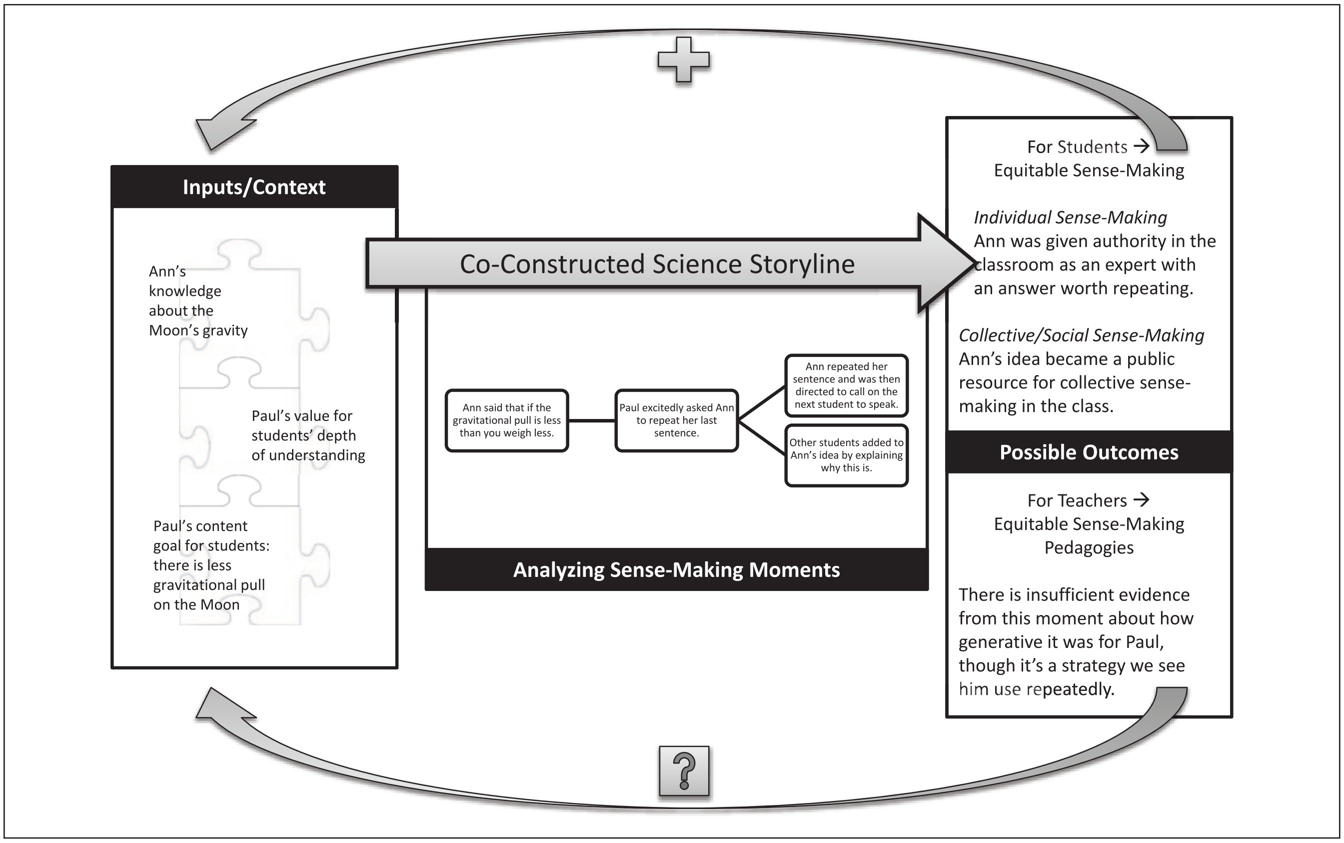

Figure 3. A model of Paul's strategy of highlighting students' ideas.

these moments, Paul elevated student voice in the lesson and made space for student sense-making, but he did so while maintaining more control over the science storyline. In the following example, note how Paul highlights a student idea aligned with the science storyline:

Ann: The, um, gravitational pull- or, the way you weigh less is because the gravitational pull, it pulls you up, I mean, like 28% less or something? On the Moon. And if the gravitational pull is less than you weigh less?

Paul: Wooh! I love that last sentence. Could you repeat that last sentence for me?

Ann: If the gravitational pull is less than you weigh less?

Paul: If the gravitational pull is less . . . thumbs up! Sideways, down. If the gravitational pull is less, you weigh less. I see a lot of thumbs up. All right. Um, but why? Why is the gravitational pull less on the Moon? Ann, would you like to call on somebody?

Ann: Um, Justin. [Justin was jumping up and down raising his hand.]

Paul's use of this strategy supported his planned science storyline. In this lesson, Paul wanted his students to understand that people weigh less on the Moon than on Earth because there is less gravitational pull (see Figure 3). Thus, Ann's answer that "if the gravitational pull is less than you weigh less" aligned well to his learning goal, which explains why he got so excited. Paul retained some epistemic authority as he maintained his science storyline, but he also made space for some equitable sense-making by sharing some authority with Ann. Paul asked Ann to repeat her idea, and his line of questioning thereafter about the gravitational pull on the Moon built off her idea toward his learning goal.

In this moment, Paul made space pedagogically for Ann's voice in the classroom without needing to make space epistemologically because Ann's way of thinking about gravity in this case aligned with his own. Nevertheless, this strategy may support some equitable sense-making because by making space for student voice, Paul positioned Ann as knowledgeable, rather than maintaining expertise within himself. This resulted in a partial disruption of normalized structures of power and position.

Paul tried the "highlighting" strategy when he noticed student contributions that converged with his intended science storyline, but he tried different responses when an idea diverged from his science storyline including calling on students who disagreed with the divergent idea, which we describe next.

Repeating Misconceptions. In this vignette, a discussion about Paul's weight on the Moon was sidelined when a student, Jess, suggested that the Moon has less gravity because it has no atmosphere pushing down on it (see Figure 4). Paul

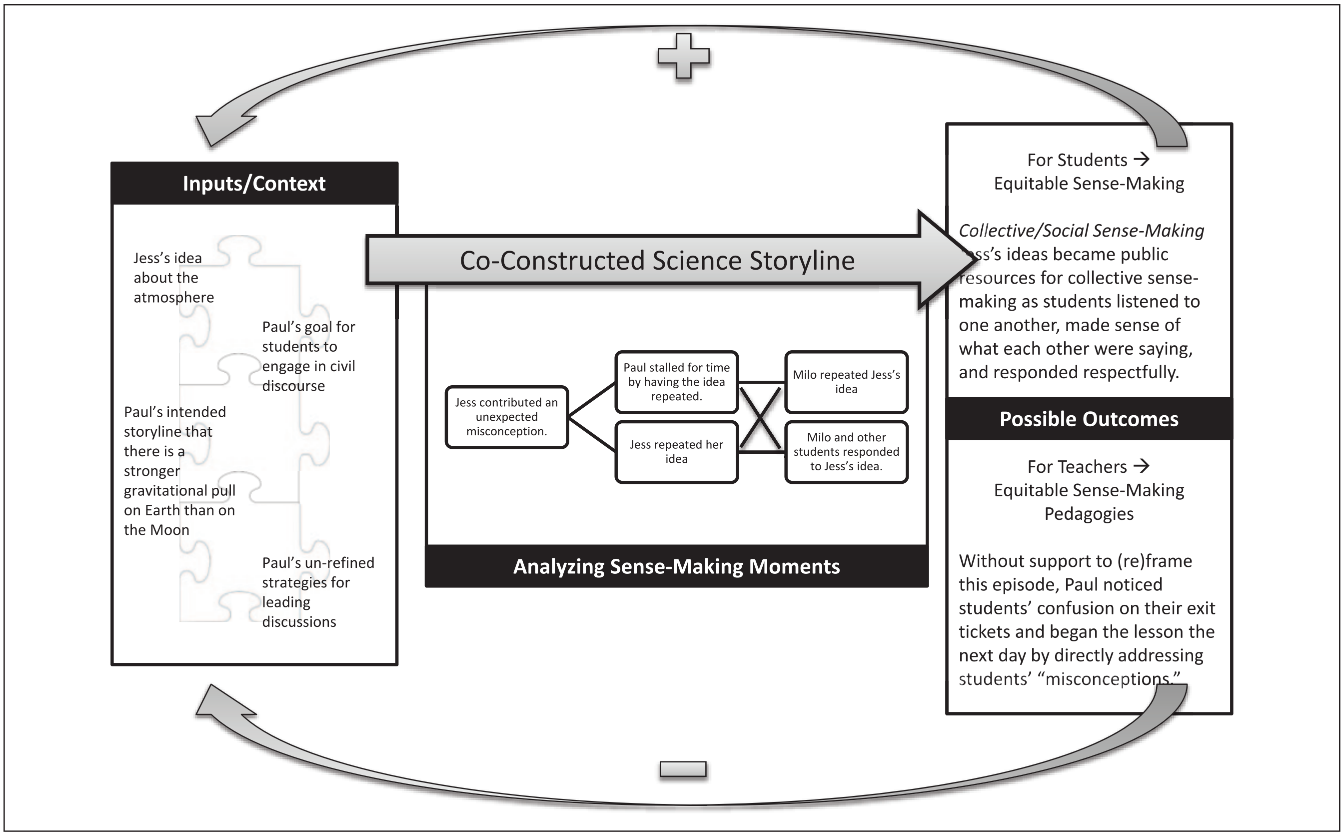

Figure 4. A model of Paul's strategy of repeating misconceptions.

interpreted this as a misconception, and his response was to have the idea repeated multiple times, believing that Jess would realize that she was wrong. As he told us in his interview,

> If you force someone to repeat it, they start thinking about it and when they, then, they will be able to say they agree or disagree because they have heard it now three times. Because Jess repeated it twice and someone else will. And so then making sure everyone is on the same page. That's my thinking at least in my mind during this.

Paul's strategy of having students repeat alternative ideas made space for epistemic authority to shift from him to a shared authority with his students as students worked through their ideas and how they understood a given phenomenon in the classroom.

Paul's use of the making space strategy in this vignette provided an opportunity for students to think about how to respond to Jess' alternative idea about atmosphere, which later led to further discussion more in line with Paul's intended science storyline. In other words, Jess' idea became a public resource for collective sense-making (see outcomes, Figure 4). Notice in the following transcript how Paul's act of making space by having Jess' idea repeated allowed for her idea to get picked up by her classmate Milo as he, and later others, worked to make sense of these ideas:

Jess: OK, I disagree a little because, um, I, well, I agree on the part that like there's different gravities. But, like, um, the um, the atmosphere is why we have more gravity is because like the Moon doesn't have an atmosphere. So if we have stuff to pull us down, but the Moon doesn't, so that's why astronauts are floating into space.

Paul: All right, so could you repeat that idea once again for us?

Jess: Because of the atmosphere, like, that pulls everybody down and keeps, well, not because of the atmosphere (indecipherable), but sort of like cuz it has that (indecipherable).

Paul: All right, so, could someone repeat Jess' idea? So, just all I'm asking for you to do is to repeat what Jess said. So I can see that you were—and that's all I want. Repeat Jess' idea. Milo.

Milo: Can I . . .

Paul: Repeat Jess' idea.

Milo: Uh, uh, there's—the atmosphere pulls us down because the . . . yeah.

Paul: Okay, yeah, so Jess is saying that uh you weigh more on Earth because the atmosphere pulls you down. And you said you disagree with that?

Milo: Yeah

Paul: And tell me why you disagree with that in a big voice so everyone can hear you.

Milo: Because if there's no atmosphere on the Moon, how would they keep the astronauts on the Moon?
Jess: Oh.

From here, Paul gave Jess an opportunity to respond, and then other students chimed in as well, with one student ultimately expressing ideas more in line with Paul's intended storyline.

This episode was generative for many students. As students listened to one another, considering the ideas of their peers, they collectively engaged in scientific sense-making. Jess equated having an atmosphere with having gravity on Earth, and suggested that without an atmosphere on the Moon, there is no gravity, and therefore astronauts float in space. Milo challenged her idea by pointing out that in fact, astronauts were able to stay on the Moon, so it must have some gravity. After this exchange, students continued contributing ideas and challenging one another, with at least one student ultimately moving away from a notion of gravity being a result of the presence of an atmosphere. Paul's move in this moment made space because he provided students with opportunities to talk with one another, relinquishing some of his own epistemic authority while students took up space with theirs. What makes this move different from his others is that Paul's intention was for students to work through what he called misconceptions by repeating them. Paul could have retained epistemic authority for himself and corrected Jess' idea. Instead, he facilitated dialogue among students in the classroom trusting that they would work through it collectively.

Another interpretation of the above moment is that a boy (Milo) took epistemic authority from a girl (Jess). This is problematic considering the underrepresentation of girls in science fields, including space science. While we share this concern, other points of evidence shift our focus away from this interpretation. In general, Paul's set of moves seems to neutralize any cisgender favoritism: he pulls sticks with students' names, alternates boy/girl, and has students call on one another. In addition, as described in previous examples, Paul frequently positions girls as experts too. Finally, Milo's challenge to Jess' idea was not the final point of the entire discussion as more students, boys and girls, contributed ideas and challenges. Given additional experience, preparation, and awareness, Paul could do more to bolster girls' contributions in class rather than simply remaining neutral. However, we maintain that this moment provided an opportunity for equitable sense-making due to a shift of authority from Paul to his students, and through a collective grappling with ideas.

Although this episode appears to have been generative for many students in the class collectively, it may not have been generative for Paul. When he asked students to write about their understanding of gravity on an exit ticket, they expressed some confusion. According to Paul,

> A couple of kids found it confusing that there were all of these ideas and they weren't sure what was right and they found it difficult to figure out what they are supposed to know.

Paul's reflection focused on students' exit tickets, and he determined that repeating misconceptions ultimately caused greater student confusion. Based on how much he valued student voice, we might have expected Paul to notice and value how students were grappling with ideas in the class discussion. Instead, Paul likely needed support to (re)frame the episode to see equitable sense-making (see outcomes, Figure 4). In other words, his evaluation was focused on correct student responses on exit tickets preventing him from noticing students' science sense-making.

Paul is unique compared with other novice teachers in our study. His vision for privileging student talk in the classroom aligned well with reform-based ideas about science instruction and led him to experiment in his practice by trying multiple strategies for enacting his vision to see what might happen. Even though he needed support to notice student sense-making, and his moves were unpolished, he repeatedly engaged students in sense-making. Many novice teachers do not share Paul's vision, including Melanie, who we profile next.

Case 2: Wait and See

Melanie was a White female intern in a predominantly White and Asian (~55% & 29%, respectively) fourth-grade classroom located in a neighboring town to Paul's. Melanie enjoyed working with older elementary students and could see herself working with this age group in her future career. Although she had positive experiences learning science in college, Melanie's science experiences in K-12 were difficult. In her interview, Melanie told us that she was "afraid" of science as a child and that "in high school I hated science because I didn't like the way I was learning it."

When asked about her role as a teacher, Melanie had a hard time answering; she felt too inexperienced. "But I think it's to get them to learn what they need to learn so far. But I know that is going to change. It's a very vague answer because I don't even know myself, almost." Melanie was more sure about her expectations of her students. She expected her students to put effort into their learning: "half of it is you, and half of it is me. You've got to learn too. You've got to put in effort, I can't just give it all to you."

Melanie worried about struggling with classroom management. For example, when reflecting on why she did not conduct a particular activity in small groups, Melanie stated, "I didn't have the skill level to manage." She was worried that students would "lose out on learning." On the other hand, Melanie's mentor teacher appeared skillful with students and had established a positive classroom community. What the mentor teacher did to accomplish this remained largely invisible to Melanie.

This case explores what happened when Melanie accidentally used differently worded questions for initiating a position-driven science discussion (Michaels, Shouse, & Schweingruber, 2008). On the board she wrote, "What is a cloud?" and in students' handouts, she wrote, "How does a cloud form?" Melanie highlighted this as a salient moment—something she identified as a pedagogical mistake. She had wanted to focus on what makes a cloud, but while editing her lesson plan late the night before, she "messed up" in her words. As she described,

> Yeah it was the same powerpoint, this video, I put, I was doing this late at night, I put "What makes a cloud" and then we did the discussion and the kids were like it's not "how does a cloud form" it's "what makes a cloud form." And I was like, "oh my goodness, this is not what I want them to be doing. I want them to be doing, 'how does a cloud form'" and I messed up in my words. And I messed up in their thinking.

When students pointed out the difference to her, Melanie reported that she did not know what to do. She, herself, was confused and did not know how to bridge the two questions. So, in the moment, Melanie *waited* while she tried to figure out her next move. Meanwhile, students took up space while they talked through the two different questions. This led students to engage more deeply with both questions as they struggled to point out the mistake to Melanie.

Waiting is different from *wait time.* We typically associate wait time with a silent pause after the teacher poses a question to the class while she waits for students to think about their responses. In this case, waiting is when Melanie experienced a moment of uncertainty in the classroom, and rather than figure out a quick way to fix it or make it tidier, she waited a moment to consider her next move. In this moment, similar to what may happen in the silent pause of wait time, students may take up space and exercise epistemic authority.

Melanie's mistake, and her in-the-moment decision to not immediately correct her mistake, yielded a sense-making exchange among students. Students argued about which position was correct: "water vapor in the sky," or "water vapor collecting on a surface." Joseph argued about the question, "what is a cloud" while Jim and his group argued about the question, "how does a cloud form." The transcript below begins with Jim attempting to point out the discrepancy between the two questions:

Jim: Well, we chose number two because it's how DOES a cloud form, not what IS a cloud. [Some students say, "Oh . . ."] So, it can't form in the SKY [raises left arm].

Joseph and a couple students: Yeah it can.

Jim: It forms on the ground and goes to the sky [raises left arm].

Joseph: It doesn't float—it doesn't float in the air, Jim, it just [several other students are chiming in as well]

Melanie: Okay, so let's let Jim and Ashley and David say their opinion, okay? So no blurting; only these people talk.

Jim: I didn't say it starts in the air, I said it started, it starts on the ground

Student: I've never seen a cloud on the ground.

Jim: [lays right hand flat on the table top] . . . when it rains there's puddles, and when it evaporates, it goes up [raises right arm up]

Student: Yeah but it's not a cloud!

Melanie: Let Jim talk

Student: That's not a cloud, that's a fog.

David: Like Jim said, it's, um, how does a cloud FORM, not what IS a cloud? And so a cloud is water vapor in the sky, and when it rains, um, there's puddles and then when it gets warm outside the puddles will, um, evaporate and then it will turn into water vapor. And then the water vapor goes up in the sky and then it turns into a cloud. It doesn't start out as a cloud in the sky.

Melanie's lack of confidence in her science content knowledge (inputs, Figure 5) made it difficult for her to figure out how to correct her mistake with the wording of the questions. We contend that the mentor teacher's rapport with students created an environment in which students could disagree with one another respectfully (inputs, Figure 5). This allowed Melanie to improvise by letting students talk through the different questions as she waited to figure out what to do (response, Figure 5). This improvisation provided space for students to engage more deeply in sense-making, sharing ideas with one another and arguing multiple perspectives (outputs, Figure 5). Students decided which question should be answered and why; Melanie supported this by allowing students space to talk. In doing so, she shared epistemic authority with them. Students contributed ideas about the composition of clouds ("water vapor"), how clouds end up in the sky ("floating," "evaporating"), and at what point we can call it a cloud ("that's a fog"). This was an equitable sense-making moment for students because they leveraged the shift in epistemic authority to construct the storyline while Melanie waited and reconsidered her next moves.

We end Melanie's case with a somewhat troubling question. In talking with Melanie about this moment, she discussed how her students were confused. She characterized this moment as "messed up"—blaming herself. Here, we noted that without support to (re)frame this episode, Melanie was unable to notice how her wait-and-see approach allowed students space to talk through the difference in questions which led to equitable scientific sense-making. Like Paul's interpretation of students' conversations about gravity, Melanie's interpretation of students' cloud conversations suggests that novice teachers need more support to be able to see and intentionally work toward equitable sense-making

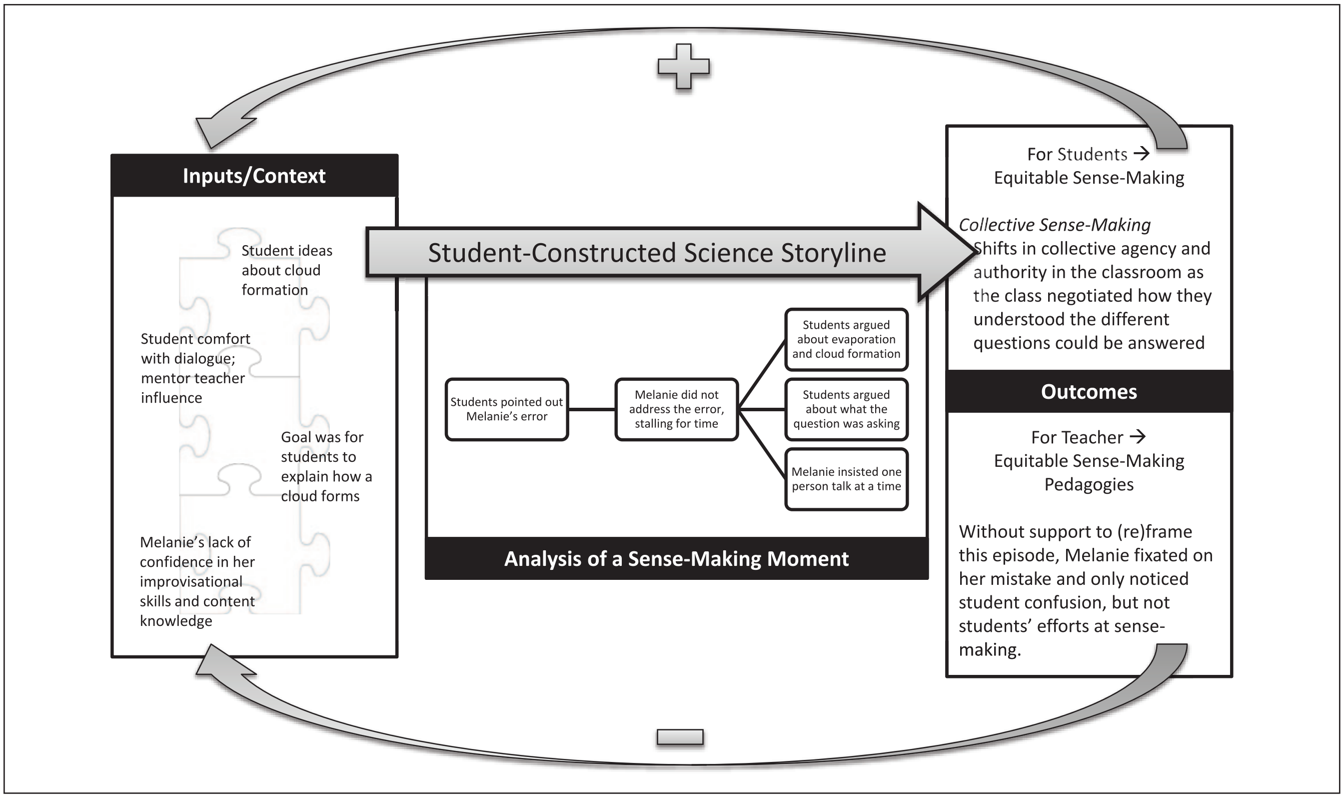

Figure 5. A model of Melanie's pedagogical mistake.

even when they are making pedagogical moves that make space for students' contributions.

Case 3: Limited Space

We end our findings section by briefly presenting a counter-example to present a limitation of making space. As we stated earlier, making space has pedagogical and epistemological dimensions. Pedagogically, teachers make space for students to contribute to the science storyline. Epistemologically, teachers make space for students' ways of knowing and thinking about science and position students as experts with authority. In the cases presented above, both Paul and Melanie made some space for equitable sense-making. Paul's students often shared ideas aligned with his own, yet he repeatedly positioned his students as experts and made space for them to share epistemic authority rather than maintaining that authority for himself. Melanie's students took up space when Melanie was unsure of what to do. Melanie pedagogically made space for students to do this, and her students constructed their own storyline as they exercised their epistemic authority in the absence of Melanie's.

In this case, we briefly introduce a third participant, Kendra, a first-year fifth-grade teacher in a nearby, predominantly White (72%) school district. Kendra is White, and she graduated from the same teacher preparation program as Paul and Melanie a few years before her participation in this study. Kendra prided herself in her science content knowledge, was pursuing her master's degree in teaching with a math and science concentration, and happily taught science and social studies to fifth graders. In a unit on evolution, Kendra's students completed a worksheet in which they labeled the parts of the digestive systems of three different animals. As they discussed this work, Kendra connected it to previous examples of single-celled organisms and how they get their food. She then contrasted this with the worm. In the following interaction, one of Kendra's students, Iris, attempted to take up space. Although Kendra pedagogically made space for Iris' contribution, Iris was not positioned as having expertise, sharing epistemic authority, or co-constructing the storyline:

Kendra: The worm was a one way out system because it had a definite in the mouth and a definite out in the anus. And it has specific organs to help it: it has a pharynx, it has an esophagus, it has a crop, it has a gizzard. Do you know what other animals have gizzards?

Students: Chicken! Birds!

Kendra: Birds! Birds, if you ever see some of them pecking at pebbles, sometimes they're actually eating those little, little pieces rock. And what they do is it goes to their gizzard and it helps them ground down food. Just like in the gizzard of a, um, of a worm, has like sand almost in there helping it grind it down.

Iris: Yeah, when my mom was little, and like, um, she would have to get the chickens, and like butcher them at home, like, she would have to, like, take out the gizzard.
Kendra: Yup.
Iris: She said it's really nasty.
Kendra: Yeah, all right, so now let's look at the guts of mammals. Do any of these have a two-way or a multiple-way digestive system?

Kendra noted that connections between what students were learning in school and their experiences outside of school were common: "This is a very common way for my students to make sense of the science content that I teach them; they are always sharing their connection building a deeper understanding." Making space is a common teacher move that Kendra uses, and her students are accustomed to taking advantage of it. After all, Iris contributed her connection without waiting to be called on, and Kendra's tone in response showed a genuine interest in Iris' story. However, Kendra did not relinquish epistemic authority to Iris, nor position Iris as an expert on gizzards for the class, nor provide space for students to co-construct a science storyline by following up on Iris' contribution. We use this as a counterexample to illustrate a limitation of making space which occurs when students contribute to classroom discourse (the pedagogical dimension of space) without resulting in equitable sense-making (the intersection of pedagogical and epistemological dimensions of space).

Discussion

Based on a close analysis of novice teachers teaching science lessons and their subsequent interviews about particular sense-making moments, we argue that one generative move novice teachers make when navigating uncertain sense-making moments in science discussions is to make space. The braiding of pedagogical and epistemological dimensions of making space is critical to move toward equitable sense-making because opportunities for meaningful student talk combined with shifts in epistemic authority allow this to happen. Our descriptions of the pedagogical and epistemological dimensions of teachers making space builds on the work of Hand (2012) by operationalizing what it may look like for a novice elementary teacher to provide opportunities for students to "take up space."

Our work also advances noticing and responding literature by considering whether teacher moves can actually foster equitable sense-making without first refining their noticing skills. Scholars often focus first on improving teacher noticing before considering responsiveness (e.g., Benedict-Chambers, 2016; Kang & Anderson, 2009; Levin et al., 2009; van Es, 2011). This prioritizing of improving teacher noticing makes sense for many reasons. Noticing logically happens before responding (Barnhart & van Es, 2015). If teacher educators can improve a novice teacher's skills at noticing, it seems logical that responsiveness will likewise improve. To better understand this succession of events, our study set out to explore what novice teachers noticed in their students' sense-making—without specially preparing the teachers to do so—and then determine how they interpreted and responded to it.

We found that Paul and Melanie each made improvisational moves fostering sense-making for students *without first engaging in sophisticated noticing and interpreting*. Other studies show that responding is among the hardest of the noticing components for novice teachers to learn (Barnhart & van Es, 2015; Jacobs, Lamb, & Philipp, 2010), yet our results suggest that novices may enact an equitable response without refined skills for noticing. This suggests that in response to well-documented challenges faced by science teachers (Braaten & Sheth, 2017; Windschitl, 2002), perhaps teacher educators could support novice teachers by working in reverse—starting with novices' teaching moves, such as making space, and using those moves as opportunities to refine novices' noticing of epistemic authority and sense-making. Once refined, more sophisticated levels of responsiveness may be easier to attain.

Making space required a shift of epistemic authority from the teacher to the students. Stroupe (2014) described students as "epistemic agents" when doing science is made public and the class is collectively responsible for knowing and doing. Cornelius and Herrenkohl (2004) identified a shift in power from the teacher to the students in their study when students had "ownership of ideas." In both studies, the shift in epistemic authority from the teacher—wherein power and authority traditionally lie—to the students was critical. Similarly, we found that the epistemological dimension of making space was essential to move toward equitable sense-making. Both Paul and Melanie shifted epistemic authority to students, for them to be "epistemic agents" and collectively work through their ideas (Ballenger, 2009). For example, instead of Paul telling Jess she was wrong about the atmosphere pressing down and causing increased gravity on Earth, he *tried* a strategy of having another student repeat her idea and then respond to it. Melanie *waited* instead of immediately fixing her mistake when she realized that she posed two different questions and allowed students to deliberate among themselves. In both cases, Paul and Melanie made pedagogical moves that allowed students to take up space and which epistemologically shifted authority from the teacher to the students. However, when Iris shared her mother's experience with chickens, though Kendra pedagogically made space for her to do so, she did not epistemologically share authority with Iris. Because Iris was not positioned as an epistemic agent, we claim that this was not an equitable sense-making moment.

Equitable sense-making is a long-term goal describing what we would like to see in science classrooms. We would like to see youth and their teachers share epistemic authority, co-construct science storylines, and disrupt norms and hierarchies of power and position in science (Calabrese Barton & Tan, 2009; Hand, 2012; Rosebery et al., 2015). This kind of teaching requires teacher noticing of students' "status and positioning" in groups as well as their "individual student histories" inside and outside of class (van Es, Hand, & Mercado, 2017, p. 266), and teachers must be first disposed to notice such things (Hand, 2012). For example, care must be taken to consider when teachers shift authority. If instances of epistemological shifts only occur when students' epistemological stances align with the teacher, then this practice will be limited and not necessarily promote equitable sense-making. The cases we offer in this article are not ideal examples of equitable sense-making. Paul did not cede epistemic authority entirely to his students, but rather steered the science storyline toward his goals. However, he did position youth as people whose ideas were worthy of being heard and challenged by their peers, instead of simply by him, which is a movement toward students having epistemic agency (Stroupe, 2014). Melanie's students took up space in the classroom to construct their own science storyline, and Melanie made space for them to do so while considering her next moves. However, vocal participants were White and male, thus maintaining established power hierarchies (Rosebery et al., 2015).

For the reasons described above, we consider one limitation of our study, that is, neither case provides an optimal example of equitable sense-making for traditionally marginalized groups in science. Nonetheless, we believe these moments, however imperfect, can serve as powerful learning opportunities for novice teachers to reflect on as they develop their teaching practices toward equitable sense-making.

Another limitation of our study is that we do not have data from students about their experiences sharing epistemic authority, or engaging in equitable sense-making. As Russ (2018) describes, the ways in which science teachers notice students' sense-making sends epistemological messages to students about learning. Our study design focused intentionally on teachers' noticing and students' classroom engagement. Future studies of this nature could benefit from collecting data about students' experiences in sense-making moments to better understand their interpretations of epistemological messaging and what learning looks like in science.

Conclusion and Recommendations

As a community, science educators continue to investigate strategies teachers may use to facilitate moments of sense-making with students, or what may make these moments equitable. Examples from Paul, Melanie, and Kendra's classrooms help us identify and unpack sense-making moments. Their cases highlight how making space for equitable sense-making shares epistemic authority with students. However, both Paul and Melanie interpreted aspects of these moments as instances of students' confusion rather than sense-making. This aligns with findings in other sense-making studies (i.e., Rosebery et al., 2015). One reason why sense-making is so difficult for novice teachers to facilitate may be that many novices interpret these moments differently, not as productive sense-making moments, but as pedagogical mistakes or student confusion. Therefore, we suggest that teacher educators may address this issue by sharing video of classroom talk with novice teachers that may appear messy and practicing noticing sense-making moments. For example, we can imagine that teacher educators might create supportive tools for novice teachers to use when viewing these videos which might help direct their attention to the substance of students' thinking in the sense-making moments themselves.

In addition, we propose that teacher educators may take up the framing of "making space" with novice teachers as a way of introducing them to the notion of taking their time to respond, centering students' voices, and not feeling rushed to maintain epistemic control. Paul and Melanie were unlikely to have learned about noticing and responding, sense-making, or epistemic authority in their science methods courses, and they were not taught to "make space." However, they each employed this strategy under different circumstances. Equitably noticing students' sense-making and responding in equitable ways are practices teacher candidates can learn and refine over time (Benedict-Chambers, 2016; Kang & Anderson, 2015; Levin et al., 2009; van Es & Sherin, 2002). In the meantime, our study suggests that novice teachers may benefit from learning pedagogical and epistemological moves like making space to practice sharing epistemic authority with students, a move profoundly shaped by power dynamics regarding whose and what knowledge matters most in classrooms. Practicing moves such as making space gives novices opportunities to facilitate more equitable classroom discourse, especially with respect to racial and gender equity.

Finally, although data presented in this article do not fully show novice teachers facilitating our vision of equitable sense-making in classrooms, we believe they have remarkable elements, and as such, we remain optimistic about novices' abilities to foster equitable sense-making in classrooms. To this end, we believe our data points to the need for teacher educators to more explicitly teach about issues of race, gender, and power in science education in addition to equitable and disciplinary forms of sense-making. Leveraging work by Bang et al. (2017), Rosebery et al. (2015) and others, we are currently incorporating these themes explicitly across all sections of our elementary science methods courses. We view making space as a critical tool novices can strategically call upon to share epistemic authority and work towards disrupting settled hierarchies of power as they help their students make sense of science.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed the following financial support for the research, authorship, and/or publication of this article: We would like to thank the National Science Foundation for its support on grant RC103139 for funding to conduct this study.

References

Ball, D. L., & Forzani, F. M. (2009). The work of teaching and the challenge for teacher education. *Journal of Teacher Education*, *60*(5), 497-511. doi:10.1177/0022487109348479

Ballenger, C. (2009). *Puzzling moments, teachable moments: Practicing teacher research in urban classrooms*. New York, NY: Teachers College Press.

Bang, M., Brown, B. A., Calabrese Barton, A., Rosebery, A. S., & Warren, B. (2017). Toward more equitable learning in science. In C. Schwarz, C. Passmore, & B. J. Reiser (Eds.), *Helping students make sense of the world using next generation science and engineering practices* (pp. 33-58). Arlington, VA: National Science Teachers Association.

Barnhart, T., & van Es, E. (2015). Studying teacher noticing: Examining the relationship among preservice science teachers' ability to attend, analyze and respond to student thinking. *Teaching and Teacher Education*, *45*, 83-93.

Benedict-Chambers, A. (2016). Using tools to promote novice teacher noticing of science teaching practices in post-rehearsal discussions. *Teaching and Teacher Education*, *59*, 28-44.

Braaten, M., & Sheth, M. (2017). Tensions teaching science for equity: Lessons learned from the case of Ms. Dawson. *Science Education*, *101*(1), 134-164. doi:10.1002/sce.21254

Calabrese Barton, A., & Tan, E. (2009). Funds of knowledge and discourses and hybrid space. *Journal of Research in Science Teaching*, *46*(1), 50-73. doi:10.1002/tea.20269

Carlone, H. B., Haun-Frank, J., & Webb, A. (2011). Assessing equity beyond knowledge- and skills-based outcomes: A comparative ethnography of two fourth-grade reform-based science classrooms. *Journal of Research in Science Teaching*, *48*(5), 459-485. doi:10.1002/tea.20413

Carroll, T. G., & Foster, E. (2010). *Who will teach? Experience matters*. Washington, DC: National Commission on Teaching and America's Future (NCTAF).

Corbin, J., & Strauss, A. (2014). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Washington, DC: SAGE.

Cornelius, L. L., & Herrenkohl, L. R. (2004). Power in the classroom: How the classroom environment shapes students' relationships with each other and with concepts. *Cognition and Instruction*, *22*(4), 467-498.

Engle, R. A. (2012). The productive disciplinary engagement framework: Origins, key concepts and developments. In D. Y. Dai (Ed.), *Design research on learning and thinking in educational settings: Enhancing intellectual growth and functioning* (pp. 161-200). New York, NY: Routledge.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction*, *20*(4), 399-483.

Engle, R. A., Langer-Osuna, J. M., & de Royston, M. M. (2014). Toward a model of influence in persuasive discussions: Negotiating quality, authority, privilege, and access within a student-led argument. *Journal of the Learning Sciences*, *23*(2), 245-268. doi:10.1080/10508406.2014.883979

Forman, E. A., & Ford, M. J. (2014). Authority and accountability in light of disciplinary practices in science. *International Journal of Educational Research*, *64*, 199-210. doi:10.1016/j.ijer.2013.07.009

Goodwin, C. (1994). Professional vision. *American Anthropologist*, *96*(3), 606-633. doi:10.1525/aa.1994.96.3.02a00100

Greeno, J. G. (2006). Learning in activity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 79-96). New York, NY: Cambridge University Press.

Hammer, D. (1995). Student inquiry in a physics class discussion. *Cognition and Instruction*, *13*(3), 401-430. doi:10.1207/s1532690xci1303_3

Hand, V. (2012). Seeing culture and power in mathematical learning: Toward a model of equitable instruction. *Educational Studies in Mathematics*, *80*(1/2), 233-247. doi:10.1007/s10649-012-9387-9

Hogan, K., Nastasi, B. K., & Pressley, M. (1999). Discourse patterns and collaborative scientific reasoning in peer and teacher-guided discussions. *Cognition and Instruction*, *17*(4), 379-432. doi:10.1207/S1532690XCI1704_2

Jacobs, V. R., Lamb, L. L. C., & Philipp, R. A. (2010). Professional noticing of children's mathematical thinking. *Journal for Research in Mathematics Education*, *41*(2), 169-202.

Kang, H., & Anderson, C. W. (2009, April). *Secondary science teacher candidates' narratives about responding to students as science learners*. Paper presented at the American Educational Research Association, San Diego, CA.

Kang, H., & Anderson, C. W. (2015). Supporting preservice science teachers' ability to attend and respond to student thinking by design. *Science Education*, *99*(5), 863-895.

Kang, H., Windschitl, M., Stroupe, D., & Thompson, J. (2016). Designing, launching, and implementing high quality learning opportunities for students that advance scientific thinking. *Journal of Research in Science Teaching*, *53*(9), 1316-1340.

Kennedy, M. M. (2005). *Inside teaching*. Cambridge, MA: Harvard University Press.

Lampert, M. (2010). Learning teaching in, from, and for practice: What do we mean? *Journal of Teacher Education*, *61*(1-2), 21-34. doi:10.1177/0022487109347321

Larkin, D. B. (2013). *Deep knowledge: Learning to teach science for understanding and equity*. New York, NY: Teachers College Press.

Levin, D. M., Hammer, D., & Coffey, J. E. (2009). Novice teachers' attention to student thinking. *Journal of Teacher Education*, *60*(2), 142-154. doi:10.1177/0022487108330245

Liston, D., Whitcomb, J., & Borko, H. (2006). Too little or too much: Teacher preparation and the first years of teaching. *Journal of Teacher Education*, *57*(4), 351-358. doi:10.1177/0022487106291976

Maskiewicz, A. C., & Winters, V. A. (2012). Understanding the co-construction of inquiry practices: A case study of a responsive teaching environment. *Journal of Research in Science Teaching*, *49*(4), 429-464. doi:10.1002/tea.21007

McLaughlin, D. S., & Calabrese Barton, A. (2013). Preservice teachers' uptake and understanding of funds of knowledge in elementary science. *Journal of Science Teacher Education*, *24*(1), 13-36.

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science!: Putting research to work in K-8 science classrooms* (National Research Council. Board on Science Education). Washington, DC. The National Academies Press.

Nasir, N. S., Rosebery, A. S., Warren, B., & Lee, C. D. (2006). Learning as a cultural process: Achieving equity through diversity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 489-504). Cambridge, UK: Cambridge University Press.

National Research Council. (2007). *Taking science to school: Learning and teaching science in grades K-8* (R. A. Duschl, H. A. Schweingruber, & A. W. Shouse, Eds.). Washington, DC: The National Academies Press.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Rosebery, A. S., & Warren, B. (2008). *Teaching science to English language learners: Building on students' strengths*. Arlington, VA: National Science Teachers Association Press.

Rosebery, A. S., Warren, B., & Tucker-Raymond, E. (2015). Developing interpretive power in science teaching. *Journal of Research in Science Teaching*, *53*(10), 1571-1600. doi:10.1002/tea.21267

Russ, R. S. (2018). Characterizing teacher attention to student thinking: A role for epistemological messages. *Journal of Research in Science Teaching*, *55*(1), 94-120. doi:10.1002/tea.21414

Schoerning, E., Hand, B., Shelley, M., & Therrien, W. (2015). Language, access, and power in the elementary science classroom. *Science Education*, *99*(2), 238-259. doi:10.1002/sce.21154

Schwarz, C., Braaten, M., Haverly, C., Calabrese Barton, A., & de los Santos, E. (2018, March). *Noticing and responding moments as windows for disciplinary and equitable sense-making.* Paper presented at the Annual International Conference of the National Association of Research in Science Teaching, Atlanta, GA.

Seiler, G. (2001). Reversing the "standard" direction: Science emerging from the lives of African American students. *Journal of Research in Science Teaching*, *38*(9), 1000-1014. doi:10.1002/tea.1044

Sharma, A., & Anderson, C. W. (2009). Recontextualization of science from lab to school: Implications for science literacy. *Science & Education*, *18*(9), 1253-1275. doi:10.1007/s11191-007-9112-8

Sherin, M. G., Russ, R. S., Sherin, B. L., & Colestock, A. (2008). Professional vision in action: An exploratory study. *Issues in Teacher Education*, *17*(2), 27-46.

Stroupe, D. (2014). Examining classroom science practice communities: How teachers and students negotiate epistemic agency and learn science-as-practice. *Science Education*, *98*(3), 487-516. doi:10.1002/sce.21112

Tan, E., Calabrese Barton, A., Varley Gutiérrez, M., & Turner, E. E. (2012). *Empowering science and mathematics education in urban schools*. Chicago, IL: The University of Chicago Press.

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. *American Educational Research Journal*, *50*(3), 574-615.

van Es, E. A. (2011). A framework for learning to notice student thinking. In M. G. Sherin, V. R. Jacobs, & R. Philipp (Eds.), *Mathematics teacher noticing: Seeing through teachers' eyes* (pp. 134-151). New York, NY: Routledge.

van Es, E. A., Hand, V., & Mercado, J. (2017). Making visible the relationship between teachers' noticing for equity and equitable teaching practice. In E. O. Schack, M. H. Fisher, & J. A. Wilhelm (Eds.), *Teacher noticing: Bridging and broadening perspectives, contexts, and frameworks* (pp. 251-270). Cham, Switzerland: Springer.

van Es, E. A., & Sherin, M. G. (2002). Learning to notice: Scaffolding new teachers' interpretations of classroom interactions. *Journal of Technology and Teacher Education*, *10*(4), 571-596.

van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. *Teaching and Teacher Education*, *24*(2), 244-276.

van Es, E. A., & Sherin, M. G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education*, *13*(2), 155-176. doi:10.1007/s10857-009-9130-3

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A. S., & Hudicourt-Barnes, J. (2001). Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching*, *38*(5), 529-552.

Wickman, P. O., & Östman, L. (2002). Learning as discourse change: A sociocultural mechanism. *Science Education*, *86*(5), 601-623. doi:10.1002/sce.10036

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, *72*(2), 131-175.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878-903. doi:10.1002/sce.21027

Yin, R. K. (2014). *Case study research: Design and methods*. Thousand Oaks, CA: SAGE.

Author Biographies

Christa Haverly is a doctoral candidate in curriculum, instruction, and teacher education at Michigan State University. Her research focuses on exploring supports inservice elementary school teachers benefit from to be more responsive to students' scientific sense-making in both disciplinary and equitable ways—that is, a merging of attending to equity issues at the macro and meso levels with attending to disciplinary science ideas at the micro level. She is particularly interested in leveraging teachers' expertise as practitioners in her research.

Angela Calabrese Barton is a professor in the Department of Teacher Education at Michigan State University. Her research, which is grounded in critical sociocultural frameworks and participatory methodologies, focuses on understanding and designing new possibilities for equitably consequential teaching and teacher learning, and its support of more expansive learning outcomes for youth, including critical agency, identity work, and social transformation. She also focuses on designing and leveraging new methodologies for embracing authentic research + practice partnerships that attend to practitioner and youth voice, and critically engages the goals of equity and justice.

Christina V. Schwarz is an associate professor in teacher education at Michigan State University. Her research focuses on enabling students and teachers (PK-16) to understand and engage in scientific practices. She also works with beginning teachers to support and enhance their pedagogical practices including noticing and responding to scientific sense-making from disciplinary and equitable perspectives.

Melissa Braaten is an assistant professor in the School of Education at the University of Colorado Boulder. Her research focuses on the complexities of teaching science in culturally sustaining and responsive ways that disrupt injustices and advocate for justice. In research partnerships with teachers, Melissa draws upon teachers' expertise and insights to refine professional learning experiences across the career trajectory and build stronger explanations of how teachers learn.