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Improvisational science discourse: Teaching science in two K-1 classrooms

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Abstract

Improvisational teaching is informed both by students' interests and ideas and teachers' deep understandings of curricular goals; it is purposeful, but not predetermined. This approach contrasts with teacher-dominated classroom discourse in which discussions are controlled by the teacher and focused on the transmission of facts.This paper examines the instructional practices of a pair of exemplary K-1 teachers in order to better understand how they responded to students' unexpected insights about science to further their participation in scientific practice. The analysis focuses on two episodes in which the teachers improvisationally transformed students' unexpected insights. We identify discourse strategies that helped the teachers provide the structure and flexibility for students to improvise scientifically: *positioning students as scientists* and *expanding scientific repertoires*.

Keywords: Improvisational discourse; Elementary science

> *"Each true jazz moment ... springs from a contest in which each artist challenges all the rest, each solo flight, or improvisation, represents ... a definition of his identity: as individual, as member of the collectivity and as link in the chain of tradition."* (Ellison, 1964 cited in Soules, 2002)

Improvisation, in music and in social life, involves creatively using the resources at hand to devise an action or response that allows one to develop new possibilities for participation and understanding (Holland, Lachicotte, Skinner, & Cain, 1998; Monson, 1996). Improvisation is not unrestrained freedom; rather, as the quote above suggests, it involves a productive tension

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between individuality and tradition, innovation and structure. A similar tension, between individual expression and the disciplinary practices of science, characterizes the science conversations and activities in the K-1 classrooms discussed in this article.

Improvisational teaching is informed both by students' interests and ideas and teachers' deep understandings of curricular goals; it is purposeful, but not predetermined (Erickson, 1982; Sawyer, 2004). This approach contrasts with teacher-dominated classroom discourse in which discussions are controlled by the teacher and focused on the transmission of facts (Lemke, 1990; Moje, 1997). If we want students to learn to think in flexible, creative, and disciplined ways, it is important to study teaching that not only acknowledges the value of students' ideas, but also uses them as a resource for furthering their learning.

In this article, we examine the instructional practices of two exemplary[1] K-1 teachers, Ms. Rosenthal and Ms. Rivera.[2] Investigating science instruction at the K-1 level is necessary because it enables us to consider how young elementary students are introduced to the discipline and practices of science (Metz, 2000). This early experience will shape their later participation (or non-participation) in science and can fundamentally affect their views of themselves as people who do and use science. With these issues in mind, the research question that guides our analysis is: how did these two teachers respond to students' unexpected insights about science to further their participation in scientific practice? To answer this question, the analysis draws on insights from discourse analysis and ethnography to document how these teachers created the conditions under which improvising could take place in and through classroom scientific discourse.

The article begins with a description of the conceptual framework that informs this study. This discussion emphasizes the use of scaffolding students' scientific discourse as a method of inviting students into and modeling scientific ways of talking and thinking. A discussion of orchestrating and improvising as metaphors for understanding how students learn to think and act scientifically follows. We then introduce the classroom teachers and their approaches to teaching science.

The focus of the article is an analysis of two classroom scenes in which Ms. Rivera and Ms. Rosenthal improvisationally transformed students' unexpected insights to lead and deepen science instruction. The scenes, which focus on K-1 students' early study of physical science, show how the teachers provided both the structure and flexibility necessary for improvisational science discourse to occur. As our analysis suggests, improvisationally building on students' science insights has the potential to create expansive learning opportunities for students (Engeström, 1987).

1. Conceptual framework

1.1. Teaching, learning, and discourse

Our approach to understanding how teachers guide students' science learning is grounded in a situated approach to understanding learning. Specifically, we view learning as the gradual participation in the socially and historically organized practices of a community (Lave & Wenger, 1991; Rogoff, 1990). A situated perspective is useful for understanding how students learn to participate in the disciplinary practices of science because it draws attention to how classroom

[1] We base this characterization on careful analysis of the teachers' classroom practices and discussions with the teachers about their approach to teaching and student learning.

[2] The teachers' names are not pseudonyms; all other proper names are pseudonyms.

activities are organized and how participants are positioned vis-à-vis language and other cultural artifacts intended to support students' engagement in the central practices of science (Greeno & Hall, 1997; Holland et al., 1998).

In classrooms, a teacher's decisions about how an activity is introduced, the materials that will be used, and how much and what type of guidance she will provide during an activity affect how students are able to participate in science (Reveles, Cordova, & Kelly, 2004; Roth & Bowen, 1995). Discourse, understood broadly to include talk, embodied activity, and the use of cultural artifacts, is an important resource teachers use for organizing students' participation and through which students can display their understandings (Cazden, 2001). Through the use of discourse in classroom interactions, teachers can orient students in relation to scientific content and ideas, and scaffold their participation into disciplinary ways of talking, thinking, and acting (Gee, 1990; Hicks, 1995).

Classroom discourse patterns that focus on the authority of the teacher are limited in enabling students to become the kinds of people who explore ideas, ask questions, create connections between ideas and experiences, and think and act critically (Lampert, 1990). The important role of the learner in influencing and at times leading instructional interactions should not be overlooked; the give-and-take between learners and teachers is especially relevant for our discussion of science activities in which students' ideas and insights form the basis of instruction.

1.2. Orchestrating and improvising as metaphors for understanding classroom interaction

The metaphor of "orchestrating" has often been invoked to describe the structuring of classroom discourse. Orchestrating is defined as the work of "arranging . . . (to) achieve a desired . . . effect"(Houghton Mifflin, 2000). Researchers describe teachers as orchestrating classroom discourse because they have particular pedagogical goals, and decide who will speak, what ideas will be pursued, and when a lesson is over (Forman & Ansell, 2002; Kovalainen, Kumpulainen, & Satu, 2001).

The metaphor of "improvising" has been used to describe relations between structure and innovation in classroom discourse. Improvising is defined as "creating new melodies in accordance with a set progression of chords" (Houghton Mifflin, 2000). Improvising involves innovation using a standard set of musical tools (e.g. chords); it is not haphazard, but occurs within a structure (Erickson, 1982). In his analysis of teaching as improvisational performance, Sawyer (2004, p. 13) writes,

> "Conceiving of teaching as improvisation emphasizes the interactional and responsive creativity of a teacher working together with a unique group of students. In particular, effective classroom discussion is improvisational, because the flow of the class is unpredictable and emerges from the actions of all the participants, both teachers and students."

The analysis of the interplay between orchestration and improvisation in this study draws on insights from studies that emphasize the importance of the collaborative and emergent nature of teaching/learning interactions (Baker-Sennett & Matusov, 1997; Hall & Stevens, 1995; Kelly, Brown, & Crawford, 2000; Palincsar, Brown, & Campione, 1993; Saxe, 1991; Tharp & Gallimore, 1988). We extend the metaphors of orchestrating and improvising to examine the teaching and learning of science. Viewing classroom science discourse in this way enables one to consider how students learn to think and act in ways that are creative and recognizably scientific.

2. Science discourse in classrooms

Science is a discipline with particular ways of talking about, seeing, valuing, and reasoning about the world that are shared by a community (Anderson, Holland, & Palincsar, 1997; Duschl, 1990; Latour, 1987; Lehrer, Schauble, & Petrosino, 2001; Lemke, 1990). Many researchers have focused on how students learn to participate in the language and practices of science through classroom discourse (Bazerman, 1988; Brown & Campione, 1994; Crawford, 2005; Driver, Asoko, Leach, Mortiner, & Scott, 1994; Gallas, 1995; Hammer, 1997; Palincsar, Anderson, & David, 1993; Reveles et al., 2004; Schauble, Glaser, Duschl, Schulze, & John, 1995; van Zee & Minstrell, 1997). The teacher, as the classroom's foremost model of how to think and act scientifically, plays a significant role in scaffolding students into an emergent science community. While the prototypical model of scaffolding involves a one-on-one interaction between a teacher and student, researchers studying science discourse in elementary classrooms have productively linked scaffolding to learning how to participate in a community of practice (Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999; Hogan & Pressley, 1997). In whole-class discussions guided by the social norms of scientific discourse, teachers can provide opportunities for students to learn to articulate their reasoning, connect observations to claims, and engage in systematic thinking. Through their participation in classroom science discourse, teachers and students also co-construct acceptable ways of knowing and talking about science. Consider the familiar I-R-E (Initiation-Response-Evaluation) sequence in which a teacher asks a known-answer question and evaluates a student's response. This pattern emphasizes the teacher as the expert, students as passive recipients of information, and questions and the curriculum as predetermined (Mehan, 1979). This contrasts with the discourse pattern of *revoicing* (O'Connor & Michaels, 1996) in which the teacher restates a student's contribution to encourage other students to respond to it and at the same time furthers her pedagogical purposes. This move allows the teacher to influence the direction of the conversation and emphasizes the importance of the co-construction of knowledge. Through the use of discursive moves such as revoicing that capitalize on the joint construction of knowledge, teachers can provide scaffolding to support students' use of the thinking and language practices associated with science.

In inquiry-based science classrooms where great emphasis is placed on the role of students in directing science activities, analysis has focused on how teachers and students negotiate understandings (Crawford, Kelly, & Brown, 2000; Krajcik et al., 1998; Moje, Collazo, Carillo, & Marx, 2001; Polman, 2000). For example, "transformative communication" describes a discourse sequence in which teachers routinely reframed and extended students' initial conceptualizations about how to develop a science research project so they each gained new insights into the project (Polman & Pea, 2001). In this interaction, the contributions of both the students and the teacher directly affected the development of scientific understandings. Gutiérrez, Baquedano-López, and Tejeda's (1999) analysis of "third spaces" similarly emphasizes that students' contributions, which may appear to be off-topic or disruptive, can be used to lead instruction in unanticipated directions. Meaningful learning can occur in third spaces and through transformative communication because teachers allow students' ideas to form the basis for creating new understandings (Vygotsky, 1978).

This analysis builds on research that draws attention to students' contributions to science instruction. The question that guides our analysis considers how teachers respond to students' unexpected insights about science to further their participation in scientific practice. By focusing on the interactions between students and teachers, we hope to contribute to research on science instruction that views students as more active contributors to their learning.

3. Research context

3.1. School

The school in which this study took place is an elementary laboratory school located at a large, research university on the west coast of the United States. As part of its charge as a laboratory school, the school's population was designed to be ethnically, linguistically, and socioeconomically diverse. To accommodate the school's second-language learners, a bilingual (Spanish-English) strand ran through the school from pre-K to fifth grade.

3.2. Teachers

At the time of this study, Ms. Rivera and Ms. Rosenthal had taught as a team for 5 years at the K-1 level. Ms. Rosenthal taught students in a monolingual English classroom and Ms. Rivera taught students in a bilingual Spanish-English classroom. As elementary school teachers, Ms. Rivera and Ms. Rosenthal were responsible for teaching all subjects. Each teacher however had her particular passion or specialization: Ms. Rivera's was literacy and Ms. Rosenthal's was science.

The teachers shared basic beliefs about how children learn that enabled them to work together productively. Central to their views were that children and teachers are active constructors of knowledge, learning occurs through interactions with teachers, children, and parents who are all part of the extended classroom learning community, and that children should have opportunities to use multiple forms of representation in order to develop connected and deep understandings.

Ms. Rivera's teaching practice was grounded in sociocultural theories of learning and theories of social justice (e.g. Vygotsky, Freire). She believed that powerful learning could take place by helping children build connections between their home and school lives. Towards this end, she encouraged students to construct meaning by connecting experiences from their personal lives to what they were learning in class. Throughout all aspects of her instruction, Ms. Rivera emphasized the need for students to learn language (Spanish and English) and subject matter content simultaneously.

Ms. Rosenthal's approach to teaching and fostering students' learning built on similar insights about child development and learning in an extended classroom community. Her teaching practice was greatly influenced by the Reggio Emilia approach to teaching young children (Edwards, Gandini, & Forman, 1998). In particular, she believed children learn best through long-term projects and in-depth study. The Reggio Emilia approach, with its emphasis on long-term projects, documentation of children's work, and connections between the school and home communities, is similar in many ways with the sociocultural theories that informed Ms. Rivera's pedagogical practice. In bringing their different, but complementary approaches to teaching together through years of collaboration and reflective conversations, Ms. Rosenthal and Ms. Rivera developed an approach to teaching that placed children and their ideas at the center of instruction.

4. Data and analysis

4.1. Data sources

The classroom interactions analyzed in this paper were recorded as part of a larger study of teaching in long-term projects (Erickson, Jurow, Levy, Rosenthal, & Santini, 2002). Instructional activities focusing on literacy, mathematics, and science were filmed in the two classrooms over one academic year. This analysis focuses on science instruction, which was organized and taught collaboratively by the teaching team. The two classes met at least once a week for joint science instruction that included whole-class discussions and demonstrations, small-group activities led by the teachers, and hands-on, exploratory activities. Twenty science episodes were filmed over the course of the school year. Longitudinal, videotaped records enabled an analysis of participants' verbal and nonverbal actions as they engaged in science in moment-to-moment interaction and over extended periods of time (i.e. months). In addition to videotapes of classroom activities, other data sources include interviews with the teachers about the purposes of their lessons and their approach to instruction, fieldnotes written while filming classroom activities, and samples of student work.

4.2. Analytic approach

Our analysis combined insights and methods from discourse analysis and ethnography to study how teachers orchestrated and how teachers and students improvised science activities. We examined how teachers orchestrated science activities by studying how they explicitly structured activities, for example through their introductions to and conclusions of science episodes, choice of the participant structures (e.g. small group demonstration), and selection of materials to be used to support their pedagogical goals. To consider the improvisational or emergent aspects of classroom discourse, we focused on how the teachers' and students' use of talk, embodied actions, and physical artifacts mutually influenced their participation in the developing science discourse (McDermott, Gospodinoff, & Aron, 1978).

More specifically, we studied the *participation frameworks* of science episodes and how these shaped students' opportunities to engage in science (Erickson, 1995; Goffman, 1981). The participation framework or set of participant positions that open up when an utterance is spoken or another type of action is taken shapes how one is able to engage in the ongoing activity and the potential to learn through this form of participation (Goodwin, 1990; Hall & Rubin, 1998; Lave & Wenger, 1991). Tracking patterns of teachers' and students' interactions allowed us to study how the teachers' use of scaffolding and the students' participation in science conversations developed together over time.

4.3. Developing analytic categories

Analysis began with the creation of content logs describing what happened during all of the filmed classroom science activities (Jordan & Henderson, 1995). Fieldnotes written during the filming of classroom activities and during conversations with the teachers about specific lessons were coordinated with the videotapes to understand the teachers' pedagogical purposes. Themes and patterns were identified regarding how the teachers organized science instruction (Glaser & Strauss, 1967). Our analysis focuses on a pattern we argue is significant because it captured both the rigor and flexibility of the teachers' science instruction. This pattern was coded as *emergent instruction* to describe how students' unexpected insights were transformed by the teachers to lead instruction. Eleven instances of this occurred in 20 science lessons; however, this number underdetermines how often this occurred because it was the guiding principle during the latter part of the year when science instruction focused on long-term projects. An example of emergent instruction is described below:

In a whole-class discussion of how potential energy is transformed into kinetic energy, Ms. Rivera used a schematic drawing of a rollercoaster to show students the point at which such a transformation would take place. She guided a student's finger along the incline of the rollercoaster and at the top of the first "hill," she stopped and pointed out that this is where potential energy is transformed into kinetic energy. A student commented that it was "just like" when they run on a hill located next to the school. Inspired by this student's connection between his personal experience and the content of the lesson, Ms. Rivera decided to take the class on a "field trip" to the hill so they could experience the transformation between potential and kinetic energy for themselves. At the hill, Ms. Rivera asked students to label their experiences running up, reaching the top, and running back down the hill using the scientific terms (potential and kinetic energy) they had discussed over the last month. (Fieldnotes, 06/15/01)

The teachers' decisions about how to respond to students in moments such as the one described above were made on the spot, but were informed by their ideas about good scientific and pedagogical practice. Examples of emergent instruction were transcribed to document teachers' and students' uses of talk, embodied activities, and physical materials. We then analyzed these interactions in terms of the participation frameworks created on these occasions and focused specifically on how the teachers scaffolded students' participation into the evolving scientific discourse community of the classroom.

5. Approach to science instruction

A central aspect of the Reggio Emilia approach is the recognition that learning occurs through multiple modalities, not only through the use of language (Edwards et al., 1998). Building on this assumption, in their science teaching, Ms. Rosenthal and Ms. Rivera purposefully used many different ways of presenting content and encouraged students to express their understandings through a variety of means including talk, writing, drawing, sculpture, and movement. Furthermore, these teachers understood that it is developmentally appropriate to help young students use these different representational resources to create concrete understandings of abstract concepts such as "matter" and "energy."

Ms. Rivera's and Ms. Rosenthal's instructional decisions were based on their understandings of the subject matter they were teaching, local school and national science standards, and their deep pedagogical content knowledge. They recognized that students have different ways of learning, interests, prior experiences, and linguistic and ethnic backgrounds and therefore instruction needs to acknowledge and build on this diversity (Gutiérrez et al., 1999; Schultz, 2003).

At the time of this study, physical science was the focus of instruction. The year began with the study of the characteristics of matter [September–January], which was followed by investigation of the movement of matter [January–April]. The year ended with a focus on forms of energy (kinetic and potential) through the enactment of a multi-week project that involved building a mini-roller coaster using simple machines [April–June]. The analysis presented in this article is based primarily on science instruction that took place during the first part of the year [September–January].

In order to make Ms. Rivera's and Ms. Rosenthal's approach to teaching more concrete and to provide background to the focal scenes, the following example is used to describe science instruction during the first part of the year. As part of their study of the characteristics of matter (solids, liquids, and gases), the teachers had students use words and their bodies to explore and represent different aspects of solids. Ms. Rosenthal, for example, asked students to "show (her) a *rough* piece of wood" and other words used to describe solids using their bodies (Content Log 09/27/00). In response, students twisted and stretched their arms and legs to create pointy edges and irregular shapes. Through these activities, students were encouraged to develop an embodied understanding of matter. Students also created lists of words and drawings to describe the experiences of touching, hearing, seeing, tasting, and smelling different forms of matter. These varied ways of exploring and representing understandings of matter contributed to a shared discourse that included words, different ways of moving their bodies, and physical artifacts that supported the students' learning of science. The next section presents scenes that took place during the students' early investigation of the characteristics of matter, specifically solids and liquids.

6. Improvisational science discourse

6.1. Scene 1: ". . . If you wiggle como una Coca Cola"

6.1.1. Background

This scene takes place at the end of September; students had been investigating the characteristics of solids since the beginning of the month. In this activity, Ms. Rivera is leading the students in an experiment focused on the idea that matter (specifically solids and liquids) occupies space. The activity began with students making predictions about what they thought would happen when rocks and sand are added to a jar of water. A goal of the experiment was to have students notice the displacement of water as the rocks and sand are added. After sharing their predictions, Ms. Rivera performed the experiment and guided students to make observations, link these to their predictions, and develop explanations for their observations. Following the experiment, students represented through drawing and writing what they observed.

As a way of introducing the activity and the students' roles in it, after students shared their predictions, Ms. Rivera referred to them as "awesome scientists." In this way, she positioned them as scientists engaged in the premier scientific activity of experimenting.

6.1.2. Activity

In this scene, Ms. Rivera was seated on the rug with 10 students who were tightly gathered around a jar filled with water. The group included girls and boys, first and second year students from both classes, and native Spanish/English language learners and native English speakers. The scene begins as Ms. Rivera prepared to pour sand from one jar into another jar that was partially filled with water and rocks. The teacher designated Leon as the "finger meter," the person who will keep his finger on the water-jar to mark its current level. This was an important role because Ms. Rivera wanted students to see the change in the level of the solution as sand was put into the jar. Before pouring, Ms. Rivera asked Sylvia, a shy, native Spanish speaker in her second year in the class, for her prediction:

09/27/00

1	Ms. Rivera:	Can you see? Leon has his finger (on the jar). What's your prediction?
2	Sylvia:	Um, the water's gonna with the other rocks at the bottom it's gonna turn a little higher.
3	Ms. Rivera:	[Just with the rocks?
4	Bradley:	[Yeah that's what I think. And it's also if you leave the sand in it it's gonna sink because it's also gonna be quicksand.
5	Ms. Rivera:	(looks at Bradley as if starting to speak and then turns to Sylvia) What about the sand?
6	Ms. Rivera:	(to Sylvia) What about the sand?

09/27/00

7	Sylvia:	It'll get-the water um the water will get muddy.
8	Ms. Rivera:	It will get muddy. Will the wa-Will the water rise or stay the same if I only put in sand?
9	Sylvia:	(softly and slowly) It will rise.
10	Ms. Rivera:	Why- oo::h good word. It will ri::se. Why will it rise?
11	Sylvia:	Because um=
12	Ms. Rivera:	(to the other students) Shhh
13	Sylvia:	= the water is a little high and with these rocks and the sand the rocks are gonna go right there. It'll make it higher and with the sand they will (inaudible) muddy
14	Ms. Rivera:	It'll make it muddy.
15	Bradley:	It will also make quicksand (turns to the camera and smiles)
16	Ricardo:	(Looks at the camera smiling) Quicksand
17	Ms. Rivera:	Let's find out.

In this exchange, Ms. Rivera helped Sylvia focus on whether or not the solution will rise. During the exchange between the teacher and Sylvia, Bradley,[3] an outspoken and articulate, second year student in Ms. Rosenthal's class, mentioned how he thought the water and sand would produce "quicksand." Ms. Rivera silently acknowledged, but chose not to follow up on Bradley's comment. Rather, she decided to focus her attention on Sylvia to encourage her participation in the activity.[4]

Sylvia began her prediction by stating that the water "will turn a little higher" with the addition of the sand. In her response, Ms. Rivera emphasized both scientific content and process and scaffolded Sylvia's English language development. Specifically, she highlighted the potential change in the water level by asking explicitly if the solution would "rise or stay the same?" thereby alerting the students to attend to the relevant aspect of the experiment (i.e. change in water level). And, she offered the term "rise" as an alternative to Sylvia's more awkward use of the phrase "turn a little higher." When Sylvia tentatively responded that the solution will "rise," Ms. Rivera repeated and praised Sylvia's use of the word (line 9). By focusing on Sylvia's prediction and scaffolding her response in these ways, Ms. Rivera furthered her participation both in the science activity and in the language practices of English.

Ms. Rivera then poured the sand into the water jar. As the solution settled, she directed the students to look at Leon's finger and number of students noted that the solution was "rising":

35	Ms. Rivera:	Why is it rising?
36	Bradley:	The rock and the sand are pushing it up.
37	Ms. Rivera:	(slowly) The sand and the rocks [
38	Clara:	[I KNOW WHY because the stuff is on the bottom and the water is getting higher and higher.
39	Bradley:	And you know what?
40	Ms. Rivera:	(Raises her hand to give Clara a high-five) C'mon.
41	Clara:	(Gives Ms. Rivera a high-five)
42	Ms. Rivera:	. . . What's happening at the bottom of THIS (points at the water) jar?
43	Clara:	I KNOW WHY because every time you put the stuff in it gets higher.

In response to Ms. Rivera's question about "why" the solution rose, Clara referred to the relative locations of the "stuff" (rocks and sand) and the "water" in the jar and suggested a relation between them ("the water is getting higher and higher"). At turn 43, Clara restated this idea in a more general form saying, "every time you put the stuff in, it gets higher." This idea of displacement, as mentioned earlier, was one of the Ms. Rivera's intended goals of the experiment.

[3] Bradley's father is a physicist who regularly served as a science expert in the two classrooms.

[4] Transcription conventions: (. . .) Parentheses indicates transcriber comments, = contiguous utterances are indicated with equal signs, :: elongated syllables are indicated with double colons, CAPS indicate emphasis, [onset of overlapping talk is indicated with a left bracket, and English translation is written in *italics*.

After eliciting these explanations, Ms. Rivera poured more sand into the water jar. As the solution swirled, she noticed the students' restlessness and asked them to "hold on" while the solution settled. Waiting for the solution to settle was necessary because it would allow the students to notice easily whether the water level has changed. While waiting for the solution to settle, Ms. Rivera started twirling her arms and torso in imitation of the movement of the solution.

51	Ms. Rivera:	Look at how much-hold on (lightly places her hand on the stomach of the student touching the jar). We're gonna let it, cause right now the sand is going like this (twirls forearms above her head while moving her torso and head up and down) It's dancing too. You know what they are dancing to? (repeats earlier "dancing" motion) What do you think?
52	Hector:	It's jiggling
53	Ms. Rivera:	It's doing the "Popcorn" (she and students laugh) Oh WAIT, WAIT, WAIT! Look at Leon's finger. Now look at the jar and tell me where the sand is at.

Through dancing and the use of humor, Ms. Rivera not only maintained the students' focus but she also demonstrated how to connect different kinds of experiences: a science experiment and the everyday, embodied experience of doing the "Popcorn" (the name of a dance they often did in her classroom). Once the solution settled, Ms. Rivera attempted to conclude the experiment by summarizing what had been found:

58	Ms. Rivera:	So WE KNOW then (glances at Sylvia who has just raised her hand) that matter occupies space.
62	Charlene:	Can I do it? (place her finger on the jar)
63	Ms. Rivera:	You can do it.
64	Marissa:	I want to do it!
65	Ms. Rivera:	You ca- you want to do WHAT? HERE'S our experiment. So this is what I want you to do. (Looks at Sylvia who still has her hand raised.)

Despite her attempt at concluding the experiment, a number of students were still eager to continue. A couple of the younger students in the group wanted to put their fingers on the jar (possibly to act as the "finger meter") and Sylvia, whose hand remained raised throughout Ms. Rivera's concluding comments, clearly had something to say. It is worth pointing out here that the students' enthusiasm suggests that one of the most fundamental goals of the lesson, to engage students' interests, was met. While Ms. Rivera noticed Sylvia's raised hand, because of time constraints, she tried to move on to the next part of the lesson. Sylvia insisted however on making her comment:

66	Sylvia:	Cuando, if you wiggle como una Coca Cola en un jarro y cuando lo abres it goes up y se cae *When, if you wiggle like a Coca Cola in a can and when you open it it goes up and it falls.*
67	Ms. Rivera:	¿En una Coca Cola? *In a Coca Cola?*
68	Sylvia:	No. Cuando esta en como una bote y cuando se mueve um, se va por aqui (touches jar to indicate where the Coke would go) y se [*No. When it's like in a can and when it moves it goes through here (touches jar to indicate where the Coke would go) and it [*
69	Ms. Rivera:	[Se sube, se sube (gestures as if shaking a Coke bottle) ¿Que tiene una Coca Cola? ¿Tiene . . .? *[It goes up, it goes up (gestures as if shaking a Coke bottle). What does a Coca Cola have? It has . . .?*
70	Sylvia:	Una tapadera. *A lid.*
71	Ms. Rivera:	Y tiene gas. (Looks at Sylvia who nods her head). Es agua con gas. Y entonces si le haces asi a la Coca Cola bzzzzz (sound of Coke bubbling up) ¿Que sube? ! El gas sube!

		And it has gas (Looks at Sylvia who nods her head). It is water with gas. And therefore if you do this to the Coca Cola bzzzzz (sound of Coke bubbling up) What goes up? The gas goes up!
72	Hector:	Y tambien si se te cae, y luego vola. *And also if it falls and then it flies all over the place.*
73	Carlos:	Y tambien las bubbles. *And also the bubbles.*
74	Ms. Rivera:	Las burBUjas. Okay, this is what I want you to do. *The bubbles. Okay this is what I want you to do.*

Sylvia began her contribution (turn 66) in English and quickly shifted to Spanish as she explained the relation she saw between shaking a Coke and the experiment. This, Ms. Rivera noted in a later discussion, was particularly significant because it was the first time Sylvia used Spanish to speak in front of a group. Recognizing this, Ms. Rivera responded to Sylvia in Spanish to support her thinking about science and her more active and verbal participation in the group discussion.

Sylvia's comment revealed that she was engaging in scientific practices Ms. Rivera modeled during the lesson and that were a regular part of the classrooms' science discourse. Specifically, she linked her everyday experience with a Coke to what happened to the solution in the experiment; this is similar to what Ms. Rivera did when she compared the movement of the solution to "doing the Popcorn." Sylvia pointed out that when you shake a Coke "it goes up y se cae" ("it goes up and then it falls"). This movement up and then down is similar yet contrasts with the behavior of the water in the experiment. Making comparisons across experiences is a valuable scientific practice because it is part of developing a more general understanding of the phenomena (Jurow, 2004).

In turns 69 and 71, the teacher shifted the perspective on Sylvia's comment so its primary object was transformed from an everyday object (e.g. a Coca Cola) to a scientific object that is composed of "agua con gas" (water and gas) (Wertsch, 1991). Ms. Rivera then enacted the narrative Sylvia described (wiggling a Coke) for the group and labeled the relevant events using the scientific vocabulary she had just introduced. In addition, by using big gestures to dramatize the shaking of the Coke and using sound effects to demonstrate the "bzzzz-(ing)" of the soda when it is opened, the teacher created a performance that aimed to engage all members of the group (not only the Spanish speakers).

Ms. Rivera's response demonstrated the variety of ways through which one could talk about and make sense of science (in Spanish, using your body) and the basis for scientific knowledge (personal experience). She both recognized and encouraged the students' diverse ways of making sense of science. Furthermore, through this exchange, Ms. Rivera co-created a space with the students that built on Sylvia's somewhat tangential comment to position her more centrally as a contributor to the meaning of the science experiment. In the context of this interaction, Sylvia thus moved from a shy student who needed to be encouraged to participate to one who more eagerly and confidently shared her insights.

While Ms. Rivera's comment focused on how a Coke rises because of gas, Hector's comment at line 72 picked up on the second part of Sylvia's comment, which is that the Coke also "falls." In Spanish, he stated that the Coke also "falls and then it flies all over the place." Hector's and Carlos's comments (lines 72 and 73) are relevant not only because they had each spoken very little during the experiment and now they were participating, but also because they built on and elaborated Sylvia's initial idea in Spanish. In this sense, Sylvia's comment along with Ms. Rivera's response expanded the science conversation to include more students and a diversity of language and experiential resources.

6.1.3. Summary: orchestrating and improvising science conversations

This scene involved both orchestration of the lesson by the teacher and improvisation by Sylvia and Ms. Rivera. In terms of orchestrating the lesson, the teacher did much to achieve her particular pedagogical goals, which included helping students understand that matter occupies space and engage in scientific practices. Ms. Rivera created the overall design of the lesson; she decided an experiment would be conducted to demonstrate that matter occupies space, what the experiment would involve, and how she and the students would participate in the activity. She asked students to make predictions, designated a student to mark the initial water level of the jar, directed students to notice changes in the level of the solution, and asked them to explain their claims. Ms. Rivera's use of directives ("Look at Leon's finger"), repetition of students' words ("The sand and the rocks . . ."), and open-ended questions ("Why is it rising?") allowed her to scaffold students into aspects of scientific discourse and practice. She designed the experiment and carried it out, yet within this structure there was also room for improvisation.

The improvisational discourse in which the teacher built on a student's unexpected insight about science to engage her more thoroughly in science took place in lines 66–71:

(Lines 66–68)	Sylvia made a comment linking what happens when you shake a Coke and the experiment
(Lines 69–71)	Ms. Rivera offered scientific concepts and words for describing Sylvia's insight thereby highlighting its scientific import

In these turns, Sylvia linked her personal experience with the experiment she just observed. She connected how Coke "goes up" out of its can when it is shaken with how the water was displaced when other contents were added to it. The structure of the lesson supported Sylvia as she recombined and tried to integrate her experiences; this inventive approach where one uses what is on hand to communicate and understand is central to both improvising and learning.

The content of Sylvia and Ms. Rivera's improvisation is related to the theme of the lesson, which was that matter occupies space. The teacher's idea to design an experiment using water and sand was one specific way of demonstrating the general idea that matter occupies space. Sylvia's example of what happens when you shake a Coke can be viewed as another way of illustrating this idea. As Sylvia explained, when you shake a Coke, the liquid rises and then falls. From a scientific perspective, shaking a Coke releases some of gas molecules from the liquid thus increasing the gas pressure in the can. Opening the can decreases this pressure, which allows the gas to expand and take up more space. On its (messy) way out of the can, the gas takes some of the liquid with it. Once the gas has been released, the liquid recedes or, as Sylvia put it, "se cae" ("it falls"). Viewed in this way, Sylvia's comment is more closely related to the theme of the lesson than it might initially appear. While Ms. Rivera did not fully develop the relation between shaking a Coke and gas occupying space, her response to Sylvia's comment allowed her to introduce the concept of gas. Gas is the third state of matter that was going to be discussed later in the year.

Ms. Rivera did not anticipate Sylvia's comment connecting what happens when you "wiggle" a Coke and the experiment. This type of unscripted student insight in which students make connections between science and their everyday experiences is the kind that inquiry-based approaches to teaching science aim to produce. It was at this moment that the teacher needed to construct a reply that was responsive to the student's thinking and to ideas about scientific content and practice. Ms. Rivera's response was guided by her understandings of science, pedagogy, and of Sylvia as a student. This resulted in a teaching and learning exchange that was, for Sylvia, personally relevant, validating of her experiences and ways of expressing herself, and scientifically substantive.

6.2. Scene 2: "Liquids always separates"

6.2.1. Background

This scene took place in November. The activity was organized so that small groups of students could explore and manipulate physical materials at tables that had different types of solids (a "solids table") and liquids (a "liquids table"). Ms. Rosenthal moved between groups to hear what they were finding and to help them identify differences between solids and liquids through their first-hand experiences. A goal of the activity was for students to notice that solids can be more easily separated as compared to liquids. Following their explorations at the solids and liquids tables, students were to participate in a whole-class discussion where they could discuss and show what they had found.

In this scene, a group of five students investigated liquids at a liquids table. On the table were different types of liquids including water, shampoo, molasses, and oil. The students in the group included boys and girls, first and second year students from both classes, four native English speakers and one native Spanish/English language learner. Immediately prior to their work at the liquids table, this group of students had investigated solids at a similarly organized solids table.

To frame their activity, Ms. Rosenthal introduced the exploration stating, "All of you are chemists. You are going to start mixing all the different liquids together. See what you come up with." As Ms. Rivera did in Scene 1, Ms. Rosenthal suggested a relation between the students, the materials, and the activity wherein the students were expected to be active science investigators.

6.2.2. Activity

On their own at the liquids table, the students quickly became deeply engaged with mixing the liquids together. When Ms. Rosenthal checked on their activities a few minutes later, she prompted them to "start thinking about the differences between your experiences" with the solids and liquids.

11/15/00

54	Bradley:	Liquids always separates.
55	Ms. Rosenthal:	Liquids can separate? [How do they separate?
56	Bradley:	[(nods head in agreement)
57	Ricardo:	No, you cannot separate.
58	Bradley:	Unless you like mix them together with something. No, you can mix them together with your own hands but if you just pour them together they separate.
59	Ms. Rosenthal:	If you pull- how can you separate? Where are they separating?
60	Bradley:	You know (moves loosely cupped hands together and then apart)? It looks like they're not, but they are like in different categories really close together.
61	Ms. Rosenthal:	Close together.
62	Harshad:	Ms. Rosenthal?
63	Ms. Rosenthal:	What?
64	Harshad:	Once you've already poured one and you pour the other they just go on top of each other.

In response to the teacher's question about the differences between solids and liquids, Bradley (line 54) made the general claim that "liquids always separate(s)." Ms. Rosenthal asked Bradley to explain "how" they could be separated. This led Bradley and then Harshad to explain what they meant by "separate." Bradley explained and showed how you could "mix" the liquids together with your hands but if you simply poured the liquids on top of each other they would remain in "different categories." He also referred to his observation of the liquids stating, "It (the liquids) looks like they're not, but they are like in different categories really close together." To push the students to back up their claims, Ms. Rosenthal posed a challenge that involved providing proof for Bradley's statement:

70	Ms. Rosenthal:	Are you ready for my question? (students continue mixing liquids) Actually, I'm going to ask you to do something for me. I'm going to ask you now, in this other cup that you have, separate your liquids, please. Separate the molasses, separate the oil, and separate the shampoo for me.
71	Ella:	(looks at teacher as she walks away) Ho::w?
72	Sofie:	We're just supposed to separate the liquids?
73	Students:	Yeah.
74	Bradley:	What?
75	Ricardo:	Ho::w?
76	Ella:	This is going to be hard.

Ms. Rosenthal's statement, "*Actually* (emphasis added) I'm going to ask you do something for me," indicated she was making an on-the-spot change to her plans. She decided to follow up on Bradley's claim and posed the challenge of "separat(ing) the liquids" to the students. Her challenge engaged the students in the fundamental scientific practice of providing evidence for their claims and led a few of them to wonder out loud about the plausibility of separating liquids.

Ms. Rosenthal again left the students so they could further investigate whether liquids could be separated. Upon her return, she noticed the students had not separated the liquids. Ella, perplexed by the challenge asked, "How, how could that be?" Ms. Rosenthal reminded them that Bradley claimed liquids always separate. She then asked:

90	Ms. Rosenthal:	Can you separate the liquids?
91	Some students:	NO.
92	Ms. Rosenthal:	Could you separate the solids?
93	Some students:	YES.
94	Ms. Rosenthal:	(pauses and holds out both hands palms up)
95	Ella:	AH HA! THAT'S THE DIFFERENCE! (points at Ms. Rosenthal) You can't- you can't separate liquids, but you could separate solids.

Ella's "ah ha!" moment (line 95) was a collaborative achievement. The teacher's questions (lines 90 and 92) were meant to lead the students to focus on whether liquids and solids could be separated. After receiving the answers she expected from the students, Ms. Rosenthal paused and waited with her hands raised as if waiting to be given what the students had found. Ella then declared the response to which Ms. Rosenthal was leading.

At this point Bradley qualified his initial comment that liquids always separate to say, "actually you can" separate "certain" kinds of liquids:

102	Bradley:	If you have certain kinds of liquids you-they don't like mix together (waves hands back and forth)
103	Ms. Rosenthal:	Like what Bradley?
104	Harshad:	Soap
105	Bradley:	Like (reaches for a bottle of oil)
106	Ms. Rosenthal:	Which liquids did you find out that don't mix easily? Like what? What is that? (points to the bottle of oil)
107	Bradley:	I don't know (laughs).
108	Ms. Rosenthal:	What is this? (reaches for the almost empty bottle of oil) What was this? (holds up the bottle)
112	Ella:	(sounding out the label on the bottle) Wes::son
113	Ms. Rosenthal:	But what is it?
114	Ella:	Wesson

115	Ms. Rosenthal:	This is, but-but what is it?
116	Ella:	Oi::l
117	Ms. Rosenthal:	It's oil!
118	Bradley:	That's what I was trying to get.
119	Ms. Rosenthal:	Oil and water do not mix easily.
120	Bradley:	I know. That's what I was trying to s-
121	Ms. Rosenthal:	So you are saying that some liquids you can separate but others you can't? Is that what you're saying?
122	Bradley:	(nods head affirmatively)

Rather than agreeing with Ella and the teacher, Bradley proposed an exception to the general claim that liquids cannot be separated. When the teacher asked which liquids do not mix, Bradley reached for the bottle of oil and Ella offered the word "oil." Ms. Rosenthal then suggested that oil and water do not mix easily. Bradley stated (line 120) that he knew this and while he did not finish his sentence, it seems he was beginning to claim that this was what he wanted to say. At line 122, the teacher checked in with Bradley to make sure she understood him and to summarize. In revoicing what Bradley ("you") tried to explain, Ms. Rosenthal made the claim more explicit and highlighted Bradley's ownership of it.

Following their explorations at the liquids and solids tables, students gathered for a whole-class discussion where they could share what they had found and possibly develop more general understandings about solids and liquids (Hall & Rubin, 1998). Ms. Rosenthal asked Bradley to bring the cup he used to mix liquids to the group so he could show and discuss what he had discovered. By positioning Bradley as such, Ms. Rosenthal created a space in which his unexpected insight ("liquids always separates") and later analysis was used to help the class develop a more nuanced understanding of the characteristics of liquids. Bradley's example underscored the importance of key scientific practices including careful observation, provision of evidential backing for claims, and the use of precise language to make scientific claims.

6.2.3. Summary: improvising a variation on a theme

In this activity, students rotated through centers while the teacher moved across the groups listening for ideas she could help them develop and eventually share as part of a larger group discussion. Ms. Rosenthal had clear ideas about the objective of the activity, however she also designed the lesson to build on students' unique insights and findings. The teacher orchestrated an activity that thrived on improvisation.

Some of the ways in which Ms. Rosenthal orchestrated the lesson included organizing the lesson as exploration of liquids and solids at centers, selecting particular materials (e.g. oil, water, shampoo) to constrain students' findings, and asking questions designed to focus students' attention on differences between solids and liquids. This structure served as a context in which students could explore and make their own discoveries.

Improvising wherein the teacher transformed a student's insight to lead instruction took place through the following sequence of activities:

(Lines 54 and 58)	Bradley claimed liquids always separate
(Line 70)	Ms. Rosenthal challenged students to provide evidence to back up this claim
(Lines 102–122)	Bradley, with help from the teacher, qualified his original claim

Across this exchange, Ms. Rosenthal and Bradley listened to, questioned, and responded to one another's ideas to develop a more sophisticated understanding of liquids than was originally intended. As in a jazz improvisation, two players, in this case the teacher and the student played off each other's contributions to create a variation on the original theme of the lesson. One of the original themes of the lesson was that compared to solids, liquids are not easily separated once they are combined. As Bradley found through his first-hand experiences with mixing liquids, however, there are certain liquids (i.e. oil and water) that appear to remain separate even when they are combined.

The understanding that emerged in this scene was developed collaboratively; it was not the product of either the teacher or the student alone. The improvisation involved interplay between Bradley's insight, the teacher's pedagogical goals, other children's contributions, and the practices of science. To improvise well it is necessary to be deeply familiar with the musical traditions in which you are playing. In this scene, Ms. Rosenthal served as the representative of the traditions of science. It was because of her knowledge of scientific discourse and her pedagogical content knowledge that she was able to help Bradley transform his initial insight into a more nuanced understanding of the characteristics of liquids. Specifically, while Bradley's claim was formulated using scientific language (e.g. referring to the category of "liquids," stating a generalization) and was based on experimentation and observation, it was not an accurate scientific statement. Throughout their exchange, Ms. Rosenthal held Bradley to the standards and practices of science. She required Bradley to support his claim with evidence ("Separate your liquids") and to use precise (from "liquids *always* separate" to "*certain* kinds" separate) and explicit ("Which liquids did you find out that don't mix easily?") language to state his claim. In addition to the teacher's support, other students in the scene also assisted Bradley in explaining his position: at line 57, Ricardo disagreed with Bradley's statement, which led Bradley to further clarify his position and at line 62, Harshad contributed to the discussion by trying to re-state what he understood to be Bradley's position. This conversation in which students disagreed with and explained their own and others' ideas was characteristic of the science talk that occurred in these classrooms and reflects the type of science discourse recommended for elementary school science (National Research Council, 1996). Through this exchange, Bradley and his classmates were able to not only learn about the characteristics of liquids, but also how to participate in the practices of science.

7. Coda

In January, Ms. Rosenthal and Ms. Rivera led the students in a review of the material they had been studying since the beginning of the year. The review focused on the characteristics of matter (i.e. solids and liquids) and was intended to provide a context for introducing gases. Bradley's father, a university physicist, was invited to lead a demonstration on different gases and their characteristics.

During the review, students recalled content they had learned earlier in the year (e.g. you can separate solids, but not liquids-except for oil and water); they also demonstrated their abilities to engage in scientific practices in which they had been gradually participating (e.g. experimenting, observing) since September (Content Log 01/16/01). For example, when the physicist used liquid nitrogen to "cool down" the molecules in a helium balloon, he told the students, "All that's left of the air (in the balloon) is a little drop of liquid." One of the students asked, "But how do we know?" and then continued, "can you shake it and hear the little drop?" The physicist remarked that proposing such an experiment is "what scientists do" and invited the student to perform her experiment in front of the class. As she conducted the experiment, her classmates looked on and eagerly shouted that they could hear the movement of the drop and claimed they saw the drop as evidence that it was all that was present in the balloon. Throughout the review session, the students demonstrated their facility with asking questions about science, testing claims, and making connections between their experiences and scientific ideas.

This coda is meant to raise the question—"But how do we know?"—as regards the analysis presented in this article. How do we know the scientific discourse in these classrooms supported students in becoming the kinds of people that ask questions and explore ideas? The analyses of the two scenes that are the focus of this article suggest that improvising in science conversations enabled students to take an active role in constructing scientific understandings and allowed them to participate in the practices of science. Analysis of the students' participation in science episodes over the first part of the school year [from September–January] suggests the students took on more responsibility for identifying questions to be studied and proposing ways of studying these questions scientifically. In the following section, discursive strategies used by the teachers to support their students' engagement and interest in science are identified and described.

8. Discourse practices for structuring scientific improvisation

Thinking of science instruction as involving interplay between orchestrating and improvising is useful because it helps describe how students learn to think creatively and in scientific ways. Teaching students to improvise in science involves inviting them into and teaching them the practices of science and creating the conditions under which they can ask questions, see new relations, and develop new possibilities for science.

While the organization of curricular activities and participant structures affects how teachers respond to students' unexpected contributions, this analysis focuses on micro-level features of the teachers' interactions with students. Two themes we identified in the teachers' discourse practices that allowed them to respond effectively to students' unexpected insights and further students' attitudes of scientific inquiry include: *positioning students-as-scientists* and *expanding scientific repertoires*. These will be discussed separately for analytic ease, but in practice they worked together to support students' participation in science.

8.1. Positioning students-as-scientists to facilitate improvisational science discourse

To improvise, students need to have a sense of the part they are going to play in science activities. In the scenes discussed in this analysis and in others in the data corpus the teachers provided a variety of resources to help students understand how to think and act scientifically. These resources included modeling how to carry out science activities and speak scientifically, scaffolding students' engagement in science through strategic questioning and the careful organization of their gradually increasing participation in science lessons, and positioning students as scientists.

The teachers routinely positioned the students as scientists and this was a main way in which they projected their expectations for the students (Nasir, 2002; Wortham, 2001). This positioning was sometimes prospective as in when Ms. Rosenthal told the students at the start of scene two that "All of you are chemists" or retrospective as in when the physicist labeled a student's proposed experiment as "what scientists do." The descriptions of who the teachers (and classroom experts) wanted students to be were not trivial assignments of identities; rather when these roles were suggested they were connected to particular ways of behaving and attitudes toward the activities. For example, after Ms. Rosenthal told the students that they are chemists, she identified what they would be doing as chemists including experimenting ("You are going to start mixing all the different liquids together") and making observations ("See what you come up with").

This positioning through language in combination with the provision of material artifacts (e.g. liquids to be explored, cups for combining liquids, and a table arranged specifically for the investigation of liquids) was a resource aimed to encourage students to take on the roles of scientists engaged in scientific activities (Holland et al., 1998). Over time and with the teachers' guidance, the students gained experience in enacting, concretely defining, and, to some extent, re-imagining these roles for themselves (Wenger, 1998). With an overall sense of the kind of participants they were meant to be and the kinds of scientific activities in which they were expected to engage, the students were given a partially structured arena in which to improvise scientifically.

8.2. Expanding scientific repertoires to facilitate improvisational science discourse

Based on analyses of the episodes in which the teachers used students' insights to lead instruction, a second theme was identified that helped them create the conditions under which students could improvise. We call this pattern *expanding scientific repertoires* and it occurred through the following sequence:

(a) a student makes an unexpected, potentially interesting comment that is connected to the science activity;
(b) the teacher leads the student in recontextualizing the comment to highlight scientific processes and/or practices; and,
(c) the teacher's response broadens the set of conceptual, linguistic, and embodied resources students can use to make sense of and engage in science.

The notion of expanding scientific repertoires is useful for this analysis because it is based on the assumption that students enter the interaction with their own ideas about science and that science is a genre that consists of particular ways of talking, acting, and thinking. To illustrate this sequence, consider Ms. Rivera's exchange with Sylvia from scene one:

(a) Sylvia made a comment in which she connected what she has observed occur in the experiment with a more everyday experience of shaking a Coca Cola.
(b) Ms. Rivera recontextualized Sylvia's statement by offering that a Coke is made up of "agua con gas" (water and gas). This transformation shifted the perspective on Sylvia's comment from an everyday to a more scientific observation. In addition to introducing the concept of gas, the teacher also modeled the scientific practice of reductionism, of breaking down a Coke to its essential parts, in order to explain its behavior.
(c) Ms. Rivera modeled how different conceptual, linguistic, and embodied resources could be used to think about science in her response to Sylvia. First, she built on Sylvia's narrative of personal experience in order to discuss scientific content. In doing so, she acknowledged this as a legitimate source of scientific insight. Second, Ms. Rivera used Spanish to speak about scientific processes and content and thereby validated Sylvia's use of her native tongue to talk about science. Third, in elaborating on what happens when you shake a Coke, the teacher used her body to model the process through which gas rises up and out of the soda can when it is shaken. This dramatic performance not only allowed her to include students who do not understand Spanish in the conversation, but demonstrated to all the students how you can use your body to make sense of science.

By providing Sylvia not with evaluations as in the ubiquitous I-R-E sequence, but with more resources with which to think about her ideas, the teacher contributed to the set of tools Sylvia could potentially use to further explore her experiences. This move is significant because it builds on what students think and encourages them to continue investigating their ideas in relation to established scientific understandings. By providing young students and English language learners in particular with scientific terminology and concepts, and by encouraging them to use embodied resources to describe their often incomplete, but potentially powerful ideas teachers enable students to enter into the developing classroom community of science practitioners (Ballenger, 1999; Fradd & Lee, 1995; Nemirovsky, Tierney, & Wright, 1998; Rosebery, Warren, & Conant, 1992).

In terms of improvising, this expanded scientific repertoire provides more material for students to draw upon, combine, and refashion as they make sense of scientific phenomena and situations. Improvising in classroom science discourse thus creates a space in which individual students can uniquely express themselves within the tradition and practices of science.

9. Discussion and implications

When science is taught as a set of procedures, a step-by-step process leading to a predetermined answer, student learning suffers (Goldston, 2005; Lemke, 1990). This approach is detrimental for students' science learning for two main reasons. First, it presents students with a superficial representation of the nature of science as a set of established facts. Second, it does not allow students to construct personally meaningful understandings that can further their engagement in science (Crawford et al., 2000). In line with current reform recommendations (see National Research Council, 1996) to teach science as a method of inquiry, this analysis argues that students can learn to use science as a tool for thinking when they are encouraged to explore ideas and improvise. Furthermore, while students at the K-1 level are often underestimated in terms of their abilities to develop sophisticated scientific understandings, this analysis demonstrates that young students have insights about science that, if recognized and appreciated by their teachers, can be used to help them develop more complex understandings of scientific content.

Improvisational science discourse is unlike traditional science instruction because it relies on students' unique insights and their teachers' tailored responses, which are informed by their understandings of their students, the subject matter, and their curricular goals. Through improvising, students can participate in and begin to view science as an inclusive, creative, and open-ended endeavor. As emphasized throughout this analysis, improvising is more than acting spontaneously or in-the-moment; teachers who improvise well have long-term plans that are open-ended in order to leave space for student involvement and collaboration (Borko & Livingston, 1989). For disciplined scientific improvisation to occur, it is necessary for teachers to structure activities so students can gain access to scientific discourse practices. The improvisational acts detailed in this article, those in which students' insights were noticed and transformed by the teacher to lead instruction, were emergent collaborations. The teachers provided their students with resources to explore and develop ways of understanding while also providing structure to the process. Students were thus given opportunities for generating ideas and making their own discoveries. We identified two discourse strategies in this study that helped the teachers provide structure for students to improvise scientifically: *positioning students as scientists* and *expanding scientific repertoires*. Together, these strategies were used to create a learning environment that fostered scientific and imaginative student thinking.

Generalizing from this study is limited by the fact that the analysis focused on a laboratory school setting and that we only studied two classrooms from this school. The teaching described in this article is meant to provide an image of what is possible under institutional circumstances that differ in significant ways from sites of more traditional elementary science instruction. For example, Ms. Rivera and Ms. Rosenthal had more freedom than their public school counterparts to modify their day-to-day instruction and they had more time and institutional support for planning and reflecting collaboratively. It is possible that these differences enabled them to respond more improvisationally to students' insights than possible in a public school classroom because there was less demand to cover the curriculum in a particular order and speed. The teachers still needed to address the "big ideas" of their school's science curriculum during the year, however, it is important to note that they had more control over both how and when this would be accomplished. The level of professionalism afforded to these teachers by the laboratory school context contributed to, but did not determine, in our opinion, the flexibility evidenced in their classroom practices. Other factors including the teachers' philosophies, training, and experiences may have also affected their instructional approaches. How these factors shape teachers' approaches to organizing and enacting science discourse is beyond the scope of this study, but it raises an important issue that we hope will be explored more thoroughly in future research.

While focusing closely on the discourse practices of two classrooms provided insight into the general nature of improvisational science discourse, we do not claim that the specific discourse practices identified in this study are the only ones that can support scientific improvising. There is certainly more to learn about how improvising relates to students' science learning and how teachers might support this type of discourse in their classrooms. Two questions, specific to the use of improvisational science discourse, raised by this study need further investigation. First, how do teachers determine whose ideas to pursue in an improvised science conversation and how do these decisions relate to issues of equity in science? Enabling all students to gain access to the kind of improvisational teaching and learning described in this study requires that teachers pay special attention to the diverse ways in which students communicate their ideas and represent their understandings. To hear the resonances between what students are saying and the content and practices of the discipline, teachers also need to have a deep understanding of their particular students and the subject matter of science. The second question this analysis raises regards how we can prepare prospective teachers to improvise with students in science. Differences between more and less experienced teachers' approaches to instruction have been described in terms of their knack for improvisational and flexibly opportunistic performance (Yinger, 1980). Experienced teachers have been found to be more responsive to students' unanticipated comments and actions than new teachers. While this may depend on experience, in part, it may also require a deeper understanding of how learning occurs through social interaction. A challenge for teacher educators then is how – particularly in today's environment of assessment and accountability – to help prospective teachers see their students as collaborators and resources for teaching and learning rather than as recipients of prepackaged knowledge.

Improvising, to return to the jazz metaphor, involves more than technical skill; it involves knowing the traditions, listening to and coordinating with members of the group, and through this, developing your own style. Improvisational science discourse, for students and for teachers, has the potential to create opportunities for a more dynamic, personally meaningful, and expansive learning experience. We think it worthwhile to learn more about the role of improvising in science teaching and learning and we hope this study encourages others to investigate this issue further.

Uncited references

Ballenger (1997), Skinner et al. (2001), Soules (2004).

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