Assessing Equity Beyond Knowledge- and Skills-based Outcomes: A Comparative Ethnography of Two Fourth-grade Reform-based Science Classrooms

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Abstract:

When evaluating equity, researchers often look at the “achievement gap.” Privileging knowledge and skills as primary outcomes of science education misses other, more subtle, but critical, outcomes indexing inequitable science education. In this comparative ethnography, we examined what it meant to “be scientific” in two fourth-grade classes taught by teachers similarly committed to reform-based science (RBS) practices in the service of equity. In both classrooms, students developed similar levels of scientific understanding and expressed positive attitudes about learning science. However, in one classroom, a group of African American and Latina girls expressed outright disaffiliation with promoted meanings of “smart science person” (“They are the science people. We aren't like them”), despite the fact that most of them knew the science equally well or, in one case, better than, their classmates. To make sense of these findings, we examine the normative practice of “sharing scientific ideas” in each classroom, a comparison that provided a robust account of the differently accessible meanings of scientific knowledge, scientific investigation, and scientific person in each setting. The findings illustrate that research with equity aims demands attention to culture (everyday classroom practices that promote particular meanings of “science”) and normative identities (culturally produced meanings of “science person” and the accessibility of those meanings). The study: (1) encourages researchers to question taken-for-granted assumptions and complexities of RBS and (2) demonstrates to practitioners that enacting what might look like RBS and producing students who know and can do science are but pieces of what it takes to achieve equitable science education.

Keywords: reform-based science | elementary science | ethnography | equity | identity

Article:

The *National Science Education Standards* (National Research Council (NRC), 1996) and subsequent NRC consensus documents (e.g., 2000; Duschl, Schweingruber, & Shouse, 2007) promote what has, in the US, come to be known as *reform-based science* (RBS), a kind of pedagogy that represents US science education's best working definition of effective science instruction. The primary justification for RBS is that it better promotes students' knowledge and understanding of scientific ideas and abilities to understand and conduct scientific inquiry (NRC, 2000), although this premise is somewhat contested (Kirschner, Sweller, & Clark, 2006; Klahr & Nigam, 2004). However, a growing body of evidence demonstrates the promise of RBS for the development of science inquiry skills and understanding of science content (Blanchard et al., 2010; Cuevas, Lee, Hart, & Deaktor, 2005; Geier et al., 2008; Hmelo-Silver, Duncan & Chinn, 2007; Kahle, Meece, & Scantlebury, 2000; Lee, Buxton, Lewis, & LeRoy, 2006; Lehrer, Carpenter, Schauble, & Putz, 2000; Lynch, Kuipers, Pyke, & Szesze, 2005; Rivet & Krajcik, 2004; Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002) and the fostering of positive attitudes about science (Cavallo & Laubach, 2001; Scantlebury, Boone, Kahle, & Fraser, 2001; Wu & Hsieh, 2006). RBS was designed with an equity aim at its core—to promote scientific literacy for all students. While there have been a few empirical studies to evaluate the potential of RBS curriculum (Geier et al., 2008; Marx et al., 2004; Wilson, Taylor, Kowalski, & Carlson, 2010) or pedagogies (Cuevas et al., 2005; Lee, Maerten-Rivera, Penfield, LeRoy, & Secada, 2008) in minimizing achievement gaps between dominant and nondominant groups and increasing diverse students' positive attitudes about science (Parker & Gerber, 2000), the literature explicitly addressing equity-related outcomes of RBS is not only scant, but also focused on narrowly defined outcomes.

Expanding What Counts as Equity

The literature about RBS and equity primarily centers on evaluating the extent to which RBS curriculum or pedagogy cultivates students' scientific knowledge (cognitive outcomes) and skills. We argue that these are important, but only partial solutions in achieving a truly equitable science education. Other equity scholars have provided arguments similar to our own in recent literature. For example, the question of "what counts as equity" takes center stage in Luke, Green, and Kelly's (2010) co-edited special issue in the *Review of Research in Education*. In the special issue, the editors push educational policymakers, practitioners, and researches to broaden their definitions of equity, stating, "The argument here is that the guidance of educational policy and practice committed to equity and social justice requires something more than approaches to accountability reliant on narrow measurement and performance indicators" (p. xiv). Tan and Calabrese Barton (2008) argue similarly:

Achievement scores, tightly aligned with content standards, remain the gold standard for documenting the impact science education has on learners, allowing other potentially powerful constructions of what it means to learn science to fall away to the side as less important. (p. 44)

One problem with focusing solely on knowledge and skills outcome measures, as anthropologists and sociologists of education and critical science education scholars have demonstrated, is that many students who are academically competent in the school subject matter ultimately view school's knowledge and skills as irrelevant for their future careers and/or everyday lives (Aikenhead, 2006; Brickhouse, Lowery, & Schultz, 2000; Calabrese Barton, Tan, & Rivet, 2008; Carlone, 2004; Eisenhart, Finkel, & Marion, 1996; Willis, 1977). Doing well on achievement measures does not necessarily, by itself, imply a successful outcome. For example, in a study that examined the potential of project-based science instruction for diverse, urban middle school students in school science, Kanter and Konstantopoulos (2010) found that students' science achievement improved; however, their attitudes toward science and their plans to include science in their futures did not change.

It is easier to define achievement as the desired outcome of education because it is easier to measure and easier to fix (Jordan, 2010). Yet, in framing equity *solely* as an "achievement gap" problem, we privilege only knowledge and skills, and overlook other knotty conceptual issues. For instance, how would the achievement gap problem help us understand the students who merely comply with classroom norms to perform good student identities, "playing Fatima's rules" (Aikenhead, 2006), but who are not intellectually engaged in/by the subject matter? Is that a successful outcome? Are we content with the results of Wood, Lawrenz, and Haroldson's (2009) study that describe a persistent and pervasive student culture of "dealing" (i.e., surviving, making do) characterized by a "checkbox view of learning" and a meaning of schooling as hoop-jumping? They argue that attempts at reform, no matter how soundly designed, will continue to fail because, in part, students' and teachers' views about the purposes of schooling clash.

The literature cited above pushes science education policymakers and researchers to reconsider what counts as equity because, clearly, closing the achievement gap is only part of the problem. Our reading of the literature and the landscape of science education raise these questions about RBS: What kinds of students are produced in reform-based classrooms (Carlone, 2004)? What does it mean to be scientific in reform-based classrooms? Who gets to be scientific? What are the processes by which "promising" and "struggling" science students get defined? How compelling, imaginable and achievable are the meanings of "science person" for different students? These are questions about equity that center culture (i.e., everyday classroom practices that imply particular meanings of "science") and identity (culturally produced meanings of "science person" and the accessibility of those meanings) (see Brickhouse et al., 2000; Eisenhart & Finkel, 1998; and Calabrese Barton, Tan, & Rivet, 2008 for similar arguments). In this article, the culture and identity lenses became critically important to understanding some puzzling outcomes, summarized below, of our year-long comparative ethnographic study of science in two fourth-grade classrooms. These outcomes would have been invisible to us had we only paid attention to students' knowledge and skills. We describe the context below.

The Equity Problem Contextualized in Two Fourth-Grade Reform-Based Classrooms

For one academic year, we studied the culturally produced meanings of “science” and “science person” in two diverse classrooms, each taught by teachers (Mrs. Sparrow and Ms. Wolfe) committed to RBS instruction. In both classes, students achieved similar levels of science understanding and nearly all students expressed positive attitudes about science and were on task and engaged in the daily scientific activities. Thus, at first glance and on traditional outcome measures of success (knowledge and attitudes), it appeared that both classrooms were equally successful in achieving an equitable science. However, we noticed differences between students' expressed meanings of and affiliations with “smart science students” in each classroom; these differences began to paint a different story regarding equity. (See Table S1, available as supplementary material accompanying the online article for evidence of teachers' similar RBS commitments. See Results Supplement, also available as supplementary material accompanying the online article, for evidence of the similar learning and attitude outcomes in each class.)

Different Levels of Affiliation With “Smart Science Student”

Our commitment to understanding the accessibility of each science class for all students demanded us to understand students' meanings of and affiliations with the culturally produced meaning of “smart science student.” One way we did so was via end-of-year interviews; we asked them to identify the three “smartest” science students in the classroom and to explain their choices by describing characteristics or behaviors of each identified student. We asked them if they shared any of the characteristics or behaviors of each identified smart science student and to elaborate on their perceived similarities and differences.

In Ms. Wolfe's classroom, all students interviewed ($n = 18$) expressed affiliation with some aspect of “smart science person” in that they either identified themselves as one of the smartest science students ($n = 6$, 33%) or they mentioned at least one characteristic they shared with those they identified as the smartest students ($n = 12$, 67%). In Mrs. Sparrow's classroom, however, 4 of 15 students (27%) identified themselves as one of the smartest science students and only 4 additional students (27%) mentioned at least one characteristic they shared with those they identified as the smartest science students. Two additional students expressed hesitancy about their affiliation with the identified smartest science students. One Latino boy said, “I do [share some characteristics with the smart science kids] a little bit, but not that much,” but could not identify any specific characteristics he shared with the smart science kids. Another Latino boy said that he “sometimes” feels like the smart science kids when he does science at home but “it's about different stuff.”

The most striking finding, however, was that five additional students (all girls, either African American or Latina) in Mrs. Sparrow's class stated*immediately*, without hesitation, that they did not share *any* characteristics of the students they identified as the smart science students. Further, throughout their interviews, these girls made comments to distance themselves from the students they identified as the smart science students. For example:

"Max, Jake, and Doug use big words and talk like scientists … I'm not like them. I don't use big words …'cause I don't know what they mean most of the time … I use the words that I know." (Tameka, African American girl)

"No, I'm not like them. I'm not that smart." (Selena, Mexican American girl)

"*They're* the science people (referring to two White boys and one White girl). We aren't like them." (N'Lisha, African American girl, pointing to two of the "recognized" White science students).

These differences in affiliation with the culturally produced meaning of "smart science student" did not correlate with our assessments of students' learning. In other words, those who expressed outright disaffiliation were not necessarily those who did not perform well on assessments. In fact, N'Lisha (an African American student) was one of the top performers on both written and performance assessments (see Supplementary Material for evidence). In other words, we could not necessarily predict students' affiliation solely by learning and skills-based outcomes. We summarize the affiliation levels across classes in Table 1.

Table 1. Affiliation with culturally produced meanings of "smart science students"

	Nominated Self as One of Three of the Smartest Science Students in Class	**Did Not Nominate Self as Smart Science Student, But Identified Self as Sharing Some Characteristics With Smart Science Students**	**Did Not Nominate Self as Smart Science Student and Did Not Identify Any Characteristics Shared With Smart Students**
Mrs. Wolfe's students	33%	67%	0%
Ms. Sparrow's students	27%	27%	46% (all students of color)

Note. We interviewed 15 students in Mrs. Sparrow's class and 18 students in Ms. Wolfe's class.

A More Narrowly Constructed Meaning of "Science Person" in Mrs. Sparrow's Class

In addition to the differences in the ways students affiliated with promoted meanings of "smart science person" in each class, we also noted the different culturally produced meaning of "smart science person" in each classroom. When we compiled all students' answers to the question that asked them to identify the characteristics or behaviors of smart science students in their class, we noticed that Mrs. Sparrow's class produced a list of characteristics that mostly reproduced narrow or prototypical descriptions of "science person" (e.g., someone who pays attention, gets all the answers right, knows a lot of stuff, uses big words). Alternatively, Ms. Wolfe's students included both prototypical descriptions of "science person" (e.g., someone who pays attention, knows a lot of things) and incorporated many more descriptions that implied a broader meaning of "science person" (e.g., someone who makes good observations, knows how to describe things, keeps trying if they get something wrong, is always thinking of experiments to do). We represent these differences in descriptions in Figure 1 below. Note that the left side of the chart represents description categories that imply fairly traditional, narrow views of "science person" (Carlone, 2004); Mrs. Sparrow's students mentioned these narrowly defined (prototypical) characteristics more often than did Ms. Wolfe's students. The right side of the chart represents description categories that imply broader views of "science person"; Ms. Wolfe's students mentioned these broader characteristics with greater frequency than did Mrs. Sparrow's students.

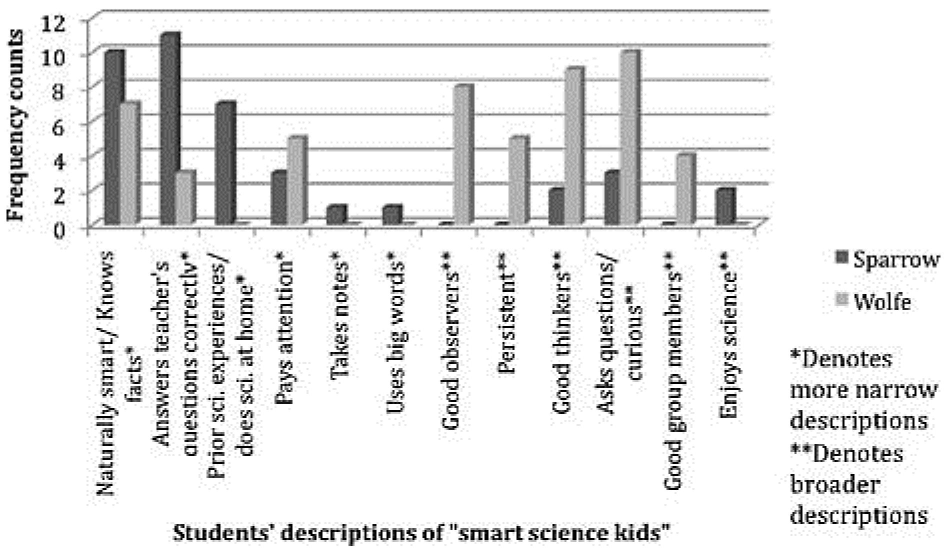

Figure 1. Students' descriptions of "smart science kids" in each classroom.

Summary of the Problem

Thus far, we have introduced the research problem that provides the impetus for this study. Despite similar learning outcomes, positive attitudes about science, and teachers' commitments to enact RBS pedagogy in each classroom, many of Mrs. Sparrow's students of color did not identify with the culturally produced meanings of "science" and "smart science person." On the other hand, every student in Ms. Wolfe's class expressed some degree of affiliation with the culturally produced meaning of "smart science person."

What happened in these two classrooms? Why such different outcomes from such seemingly similar inputs? In the rest of this article, we provide a framework for how we re-examined our ethnographic data to better understand this problem, provide thick descriptions (Geertz,1973) of how the different cultural meanings emerged from similar normative reform-based scientific practices, and explain why the cultural meanings of "science person" were differently accessible in each classroom. The argument and evidence in this article will encourage science education researchers to question taken-for-granted assumptions (including unbridled endorsement) of "RBS" and will highlight the limitations of centering research, especially that with equity aims, solely on narrowly defined outcomes of knowledge, skills, and attitudes. This article demonstrates to practitioners (teachers, teacher educators, professional developers) that enacting what might look like RBS is but a piece of achieving equitable science education. Our study uses concrete and detailed examples of analogous pedagogical practices in each classroom so that practitioners and researchers alike get a renewed understanding of science education in the service of equity.

Theoretical Framework

Sociocultural Perspectives

Sociocultural perspectives on learning guide this study, pushing us to evaluate classrooms beyond science content knowledge, skills, and attitudes (Forman & Sink, 2006). Sociocultural perspectives imply that learning science is a social and cultural process; it involves enculturation of students into the norms and practices of science and schooling (Aikenhead, 2006; Cobb, Stephan, McClain, & Gravemeier,2001; Kelly, 2007). Therefore, evaluating learning requires, in part, a unit of analysis that includes both the individual and her/his social worlds (Wertsch, 1985). Theoretically and methodologically, we must pay attention to individual outcomes, but also to the normative practices that co-produced those outcomes.

Whether or not and what we learn is a function of what we feel (or others feel) is important for us to learn. Sociocultural perspectives also imply that learning involves values and emotions. Therefore, evaluating learning means that we must consider affective dimensions (and dispositional outcomes) of learning (Cobb, Hodge, Visnovska, & Zhao, 2004). This means more than understanding students' attitudes towards science; it pushes us to examine the ways the promoted ways of "being scientific" in a classroom are meaningful, believable, and achievable for a diverse group of students.

Normative Scientific Practices

The ways to "be scientific" vary from classroom to classroom depending upon the ways its members are "expected, entitled, and obligated to participate, but also the meanings that members make of particular acts of participation" (Gresalfi, Martin, Hand, & Greeno, 2008, p. 50). Though classroom practice cannot stray too far from sociohistorical legacies of schooling and school science to be considered legitimate (Carlone & Webb, 2006), each classroom is its own social system "organized through regularities of shared practice" (Gresalfi et al., 2008, p. 50). To operationalize "practice," we draw on Kelly's (2005) definition: "practice is constituted by a *patterned set of actions*, typically performed by members of a group based on common purposes and expectations, with shared cultural values, tools, and meanings" (p. 2, our emphasis). We label the regularities of shared practice as *normative scientific practices*, which are the practices one is held accountable to in order to be considered competent in a given setting

(Cobb, Gresalfi, & Hodge, 2009). Analytically, identifying these taken-for-granted normative practices helps us define promoted meanings of “science” and “science person” in a given setting.

Identifying the meanings of “science” and “science person” in a setting requires a careful dance between recognizing their local production in practice and interaction and the ways larger, more powerful disciplinary traditions, history, and enduring cultural models shape and get shaped by these locally produced meanings (Eisenhart & Finkel, 1998). We view science as a set of emergent practices that are shaped, but not determined, by historical disciplinary traditions (Kelly & Duschl, 2002; Sandoval, 2005). Actors draw upon different resources to create a definition of “science person.” Teachers and students carry with them models of good science student from the media, their peers and families, and in-school and out-of-school science. These models shape how students get positioned and position themselves in relation to school science. Students draw on cultural models at different timescales as they come to identify with or become alienated from a local cultural model (Lemke, 2000; Wortham, 2006). For example, a historically stable model, circulating widely across time and space, is the “super-intelligent, geeky, white male” cultural model. This macro-level model shapes, but does not determine, who is perceived as being scientific in a given classroom. Other macro-level models may also shape the meaning of science person—for example, the “loud Black girl” cultural model (Fordham, 1993) may hinder an African American girl's ability to be recognized as scientific (Brickhouse & Potter, 2001). These sociohistorical models of identity are also interactionally emergent at the classroom *event level* (Wortham, 2006), which is a micro-level timescale. The same macro-level model may get taken up differently and become more or less relevant in micro-level events (Wortham,2006). Researchers often pay too much attention to either sociohistorical or event-level emergence of cultural models of identity and ignore “*months-long timescales* across which classroom-specific habitual patterns” develop (Wortham, 2006, p. 9). Actors develop local (meso-level) models of (smart, difficult, or “science-y”) student and *habitually* apply these to given students over the year. We attend to the meso-level timescale in this study.

Normative Identity versus Personal Identity

Our focus on the meso-level timescale means that our analysis does not focus on students' “personal identities” (i.e., the ways students viewed and/or described themselves in relation to science) *per se*. For nearly a decade, identity studies in mathematics and science education have highlighted the benefit of broadening the scope of analyses beyond knowledge- and skills-based outcomes, especially when examining issues of equity (Brickhouse, 2001). An analytic focus on identity allows consideration of a wide range of affective and dispositional outcomes such as the ways students view themselves in relation to science, the value they place on learning science, and their interest, commitment, persistence, and/or motivation to pursue science learning (Cobb et al., 2009). One problem of including identity-related outcomes as an analytic focus of a study, however, is that the concept can be ill defined, making its study slippery (Carlone & Johnson, 2007; Sfard & Prusak, 2005).

In response to this reasonable critique of identity studies, we look to work by Cobb et al. (2009) as a fruitful starting place to define a workable, yet rigorous way to apply the concept to our research problem:

> We take as our starting point the colloquial meaning of *identifying*, namely, to associate or affiliate oneself closely with a person or group. Our concern is both with how students come to understand what it means to do mathematics as it is realized in their classroom and with whether and to what extent they come to identify with that activity. (p. 41)

As Cobb et al. (2009) argue, shifting from identity to identifying prompts differentiation between students who identify with the classroom's science activity, students who merely comply with the classroom norms (Aikenhead, 2006) and those who resist classroom norms and potentially develop oppositional identities (Brown, 2004; Gutstein, 2003). In our study, most of the students in both classrooms claimed to “like science” (perhaps indicating a mere compliance with classroom norms), but only certain students in Mrs. Sparrow's class affiliated with the promoted ways of “being scientific.”

In this article, we examined what Cobb et al. (2009) term the *normative identities* in each classroom:

> Normative identity as we define it comprises both the general and the specifically mathematical obligations that delineate the role of an effective student in a particular classroom. A student would have to identify with these obligations in order to develop an affiliation with classroom mathematical activity and thus with the role of an effective doer of mathematics as they are constituted in the classroom. Normative identity is a collective or communal notion rather than an individualistic notion. (pp. 43-44)

Normative identity, then, can be considered the promoted ways of “being a science person” in each classroom. Identifying the normative identity means closely examining the normative scientific practices (i.e., the scientific norms one is held accountable to in order to be recognized as “scientific” by teachers and peers).

Eschewing Explanations that Focus Solely on the Individual

There is a temptation in this kind of comparative study to blame the teacher for particular classroom accomplishments. While it is true that the teachers had great influence on the cultural meanings produced in the classroom, “it would be convenient, but misleading” (Wortham, 2006, p. 26) to cite the teacher's lack of skills or knowledge as the primary explanation for why only certain children gradually came to identify with the cultural model of science person in one classroom. Processes at different timescales in both classrooms contributed to certain students' engagement and others' alienation. Further, as implied by a sociocultural perspective, classrooms' activity systems “are not defined by one member, no matter how powerful that member may be” (Gresalfi et al., 2008, p. 51). For normative scientific practices to become “normative,” regularly occurring “practices,” students must buy in and contribute to their development and maintenance and practices may not stray too far away from disciplinary practices and norms and institutional traditions to become legitimate (Carlone & Webb, 2006). Concurrently, students' agentic practices may gradually shift and transform the teacher's intended classroom normative practices (Calabrese Barton et al., 2008).

Research Questions

The research presented here is part of a larger study that examines the learning and identity affordances of RBS for students from diverse ethnicities and socioeconomic backgrounds. The purpose of the study reported here was to understand why two classrooms that promoted similar kinds of RBS practices produced differently accessible meanings of “science person.” Though there may be many explanations for these different outcomes, our sociocultural framework implies that, to understand the meanings of “science person,” we must look to the classrooms' normative scientific practices—that is, the practices in which one had to engage to be considered competent. As we discovered the different levels of affiliation in each classroom as the study progressed, we examined the data to address the following research question: What were the cultural meanings of “science person” in each classroom? Another way to ask this is: What were the relevant normative science identities in each classroom? To answer this question, we asked the following subquestions: (a) What were the normative scientific practices to which students were held accountable? (b) How accessible were the cultural models of “science person” for a broad range of students?

Study Design

We searched for exemplary fourth-grade science teachers in 70 schools within 6 school districts in the Southeast US, interviewing administrators, administering teacher surveys, observing classrooms, and interviewing teachers (Carlone, Haun-Frank, & Kimmel, 2010). After a full 8 months of site selection processes (2006–2007), we chose these fourth-grade classrooms to study ethnographically in 2007–2008 because of the teachers' outstanding commitment to and enactment of RBS, their reputation as excellent teachers among district-level and school-level administrators, and their commitment to include science as a regular part of their curriculum. Further, both classrooms had a diverse student population, and we were especially interested in the affordances and constraints of RBS for students from a wide range of races (by which we mean children's phenotypes), ethnicities (by which we mean their cultural backgrounds), and socioeconomic levels.

Research Settings

Both teachers had roughly equal amounts of teaching experience—4 years (Mrs. Sparrow) and 5 years (Ms. Wolfe), respectively. School-based and district-level administrators noted both of these teachers as exceptionally strong fourth-grade teachers. As teacher development theory would predict of teachers with 4 or 5 years of experience, both of these teachers had established management routines that worked for them (Sabers, Cushing, & Berliner, 1991). In our 58 total observations (*n* = 20 for Sparrow; *n* = 38 for Wolfe), we observed virtually no behavior problems. Both teachers lived up to their commitments to hands-on instruction; nearly every science lesson involved some sort of hands-on, small-group component that centered on a science concept or problem of interest. On paper, in interviews, and at first glance during observations, these classrooms appeared to enact "reform-based" practices on a regular basis. Table S2 illustrates further evidence for the teachers' reform-based teaching, comparing regularly occurring classroom practices in each classroom with practices of reform-based instruction recommended by the National Research Council's most recent consensus document (Duschl et al., 2007), *Taking Science to School*.

Ms. Wolfe taught at a school where approximately 40% of students received free or reduced lunch. Ms. Wolfe is a White, bilingual, 5th year teacher (at the time of the study) who was a recent awardee of Teacher of the Year in her district. The classroom was a dual-language immersion classroom, with instruction divided between English and Spanish.[1] The racial breakdown of the class was: 32% White; 58% Latino; 10% African American. Mrs. Sparrow, a 4th year teacher at the time of the study, taught at a Title I school (40% of students receiving free or reduced lunch) located in the same school district as Ms. Wolfe's school. The racial breakdown of the class was: 58% White, 21% Latino, 17% African American, 4% biracial. Mrs. Sparrow is well-known as an outstanding teacher within the district.

The populations in each classroom were also diverse in terms of socioeconomic status. In each classroom, some students had parents who worked in professions that demanded post-secondary education (e.g., as doctors, lawyers, business professionals, teachers) with salaries that ranged considerably. Many of these students lived in single-family dwellings and had wide-ranging after-school, summer, and travel experiences and opportunities. At the same time, each classroom also had students who came from less privileged backgrounds. Some students' parents worked in local restaurants, though a couple of families owned their own restaurants. Many of the students came from single-parent homes, lived in tiny apartments, and/or had parents who were either under-employed, unemployed, or struggled to make a living wage.

In both classrooms, students had a wide range of access to and experience with out-of-school science. For example, less than a handful of students in each classroom had science summer camp experiences (e.g., Boy/Girl Scouts or local university-sponsored programs). Some students had access to, and were interested in, science learning resources outside-of-school (e.g., science television programming, tradebooks, software, kits and models), but many did/were not. Some who were interested in science prior to fourth grade gained their out-of-school experiences through more informal means (e.g., helping fix the car, gardening, cooking). Many visited local science museums and centers through school fieldtrips, but third-grade science in both settings was not an emphasized part of the curriculum; it was rarely taught. Thus, it is clear that students' diverse prior science experiences and interests were not the determining factor in students' ultimate affiliation with science by the end of fourth grade.

Data Collection and Analysis

We observed nearly every science lesson during the magnetism/electricity units (22 lessons in Ms. Wolfe's classroom; 15 lessons in Mrs. Sparrow's classroom) and animal adaptation units (16 lessons in Ms. Wolfe's classroom; 5 lessons in Mrs. Sparrow's classroom) in each classroom. For this article, we focus on the magnetism/electricity units because both teachers taught similar topics for the entire unit, and we collected analogous kinds of data from each classroom for this unit. We have more observations for Ms. Wolfe's class simply because she taught more lessons. The following data were most salient for this study: videotapes of every lesson (whole-group and small group); fieldnotes written during and after observations; written student assessments; student and teacher interviews (formal and informal).

During the first few weeks of data collection, our observation protocol focused on identifying the normative scientific practices with the ultimate goal of defining the normative scientific identity (i.e., what it meant to "be scientific") in each classroom. We initially focused on identifying key epistemic (how students observe, infer, justify, evaluate, and legitimate scientific knowledge), communicative (how students communicate scientific ideas, questions, and information with one another and with their teacher as they engage in science), and investigative (how students use tools, texts, and inscriptions to investigate a natural phenomenon) practices (Kelly & Duschl, 2002). We identified the relevant practices in each classroom (e.g., observation, inference, justification, questioning, tool use) and then went back to the videotapes to code for instances of those practices. In compiling the lists, we were able to develop thick descriptions (Geertz, 1973) of what counted as "good" practice in each classroom. For example, for scientific observation, we asked: What does "observing" look like? What are the celebrated ways of observing? What are the marginalized ways of observing? What are the times and spaces for observing? What are the reasons for observing? For two practices (evaluating and legitimating scientific knowledge), we delved further by asking: Who is responsible for evaluating and legitimating scientific knowledge? We wanted to understand the extent to which each class fostered the kind of community evaluation of scientific knowledge called for in reform documents (Duschl et al., 2007; NRC, 1996).

We moved back and forth from our list of emerging practices and our videotape and fieldnote data, adding to and taking away the relevant list of practices with the goal of identifying practices present in each classroom to strengthen our comparisons. Our final list of practices included only those that emerged as important aspects of both classroom cultures—that is, those that were regularly occurring aspects of "doing science" in each classroom.

We narrowed down our list to the following practices: ask and answer scientific questions, share scientific tools and ideas, "mess about" with tools, communicate scientifically, make scientific inferences, conduct scientific observations. At this point, we revisited videotapes and fieldnotes for another round of analysis to understand better the similarities and differences between: (1) the ways each practice "played out" (i.e., what it looked like); (2) celebrated ways of enacting the practice via an examination of what behaviors got recognized by the teacher and students' behaviors that prompted bids for recognition (Gee, 1999); (3) the emergent outcomes of the practice (i.e., its implications for what counted as “science” and “science person” and the accessibility of those meanings for a wide range of students); and (4) the relative opportunities for a broad range of students to take up that practice competently. For this latter focus, we heeded Gresalfi et al.'s (2008) argument about the socially constructed nature of “competence” in any given classroom. When one views classrooms as social systems, “competence” is not viewed as a trait of an individual, but involves interaction between the students' opportunities to participate competently, the ways students' take up, transform, and/or reject those opportunities, and students' meanings of the opportunities.

During this phase of analysis, we referred to students' and teachers' “norms interview.” Towards the end of the year, we created a list of normative scientific and social practices (e.g., “We ask scientific questions”; “We investigate answers to our own questions”; “We share scientific ideas”) and community values (e.g., “We like science”; “We share tools”) present in each classroom. We conducted a card sort interview with each student and teacher, whereby students read each norm or value listed on a card, described the meaning of the norm or value for their science class (“What does it mean to do ‘good observation’ in Ms. Wolfe's class?”), and placed the card in a “yes” (i.e., This is important and/or a regular part of doing science in this class); “maybe/sometimes” (i.e., This is somewhat important and/or something we do sometimes in this class); or “no” pile. Then, they chose three cards that ranked as “most important” aspects of doing science in their class. Additionally, during this interview, we asked students and teachers to list the three smartest science students in the class, describe characteristics of each student, and decide whether or not they shared characteristics of the smart science students. This protocol proved helpful in identifying *students' and teachers' understandings and valuations* of the classroom's normative practices, values, and locally produced meanings of “smart science student” which, coupled with our detailed video and fieldnote analysis, allowed for a robust account of the normative scientific practices.

To define the culturally produced meaning of “science” and “science person” in each classroom from the rich descriptions of the normative scientific practices, we asked ourselves: What do the expectations, obligations, opportunities, purposes, and participants' understandings associated with each practice imply about the nature of scientific investigation, the nature of scientific knowledge, and the nature of scientific person in each classroom? As it turned out, this was a relatively easy task because we quickly began identifying similar meanings of scientific investigation, scientific knowledge, and scientific person across all practices in a given classroom. In other words, normative ways of conducting scientific observation yielded similar meanings of scientific investigation, knowledge, and person to normative ways of sharing scientific ideas and tools. Concurrently, at this point, we noticed pronounced differences in the implied meanings of “science” and “science person” in each classroom, which ultimately helped explain the differences in the accessibility and the affiliation in each setting.

We limit this article's scope by providing a rich account of one normative scientific practice (sharing scientific tools and ideas) and the meanings and accessibility of the meanings of “science” and “science person” implied by that practice, instead of providing a more surface-level account of all five practices (ask and answer questions, “mess about” with tools, communicate scientifically, make inferences, conduct observations).

Findings

Sharing Scientific Ideas and Tools in Mrs. Sparrow's Class: What Did it Look Like?

“Turn-taking” best summarizes the overwhelming meaning of “sharing ideas and tools” in Mrs. Sparrow's class which, on the surface, seems quite appropriate and representative of what many would define as good practice for fourth-graders. Mrs. Sparrow *expected* students to share tools and information in and between small groups: “It's not a competition,” she reminded students in class. She told us that students are “expected to [share]. Depending on their mood, sometimes, they don't want to … Some students I think would love for their classmates to just tell them the answer” (Interview, 8/13/08).

In general, students took up the turn-taking sharing practice in small groups. Below, we provide a representative excerpt of student interaction in small group during an introductory activity whereby students' task was to light a bulb by creating a closed circuit using unfamiliar tools (i.e., a battery holder, a bulb holder with Fahnestack clips, wires, battery, and bulb).

Caitlin: Guys, **can I try** something? How about like this?

Neil: Hey. **Let me try** an idea.

Caitlin: **Can I try** something real quick?

Max: Sure.

Caitlin disconnects and reconnects wires.

Max: **I** got an idea.

Neil: After Caitlin is **my idea**, Max.

Max: Okay, but then **my idea**.

Caitlin: This one doesn't light at all.

Neil: Okay, **my turn**. I'm assuming that there's … Okay. I'm assuming that there's a wire, that this wire is connected here and we may as well see if there is—

Max: **I'll** just test.

All three students fiddle with different parts of the circuit board at the same time. (Video transcript, 10/31/08)

In the full 27 minutes of small group work on this transcript, these students mentioned individually testing their ideas 40 times. Common phrases included: mine, can I try, my idea, my turn, can I see, and I have an idea. These patterns of sharing as turn-taking were prevalent across small groups and activities over time. In small groups, they shared tools, but their ideas often remained private from or ignored by other group members. Intra-group communication was even more problematic. Despite Mrs. Sparrow's directive to eschew competition between groups, students often guarded their ideas and solutions from other groups. Even the sharing in whole group discussion had a turn-taking quality to it, with each student sharing her/his individual ideas with few if any references to their classmates' previously shared ideas.

Outcomes of the Turn-Taking Practices

Since turn-taking dominated small group activities, *scientific investigation* largely meant trying out one's own ideas with tools. Students individually owned *scientific knowledge* constructed in small group tasks and in whole group discussions. When individuals made their knowledge public, they did so with little or no reference to others' ideas, and they made bids to try out their own ideas ("Let me try my idea"), often staying mum about what those ideas were. As a result, those who were able to use small group tasks as opportunities to construct deep understandings of content had to be assertive in trying out their own ideas. Typically, the more dominant (vocal, assertive) students got more time with the tools and thus, had more time to construct an understanding of the concept. Those who were more assertive in small groups got more positive recognition for their scientific ideas in the whole group setting. These practices implied that *science people*, in this class, figure things out for themselves and do not necessarily get ideas from others or productively share ideas (Engle & Conant, 2002) with others.

In this case, the meaning of "science person" (i.e., someone who is assertive in trying out their own ideas with tools) was not equally accessible to all students; not everyone got a fair opportunity to be scientific. As a result, we saw quieter students, students with less social capital, and English Language Learners take on unsanctioned roles (Calabrese Barton et al., 2008) such as "guarder" (protecting the group's solutions from other groups), "nurturer" (making sure the group had all their materials, mothering the group mates to "keep going"), and "naysayer" (shooting down everyone else's ideas). Toward the beginning of the unit, we saw two African American girls in the class (Tameka and N'Lisha, two of those who later expressed disaffiliation), quick to find a solution when they worked as a pair, trying to gain insight from other groups' work and/or offering to help other groups nearby. For example:

Doug and Jake are seriously struggling with their circuit. They cannot get their bulb to light. Tameka comes over to examine their progress.

Doug: Why are you looking—? (*speaking to Tameka*)

Tameka: We're not looking at y'all's. Leave us alone.

Later, after Tameka successfully lit the bulb, she goes back to check out what Jake and Doug are doing.

Jake: We can't do it.

Doug: We can't figure out how to do it with one (wire).

Tameka: (*Reaching in and pointing*) That's not going to help, you putting that (wire) on the inside of there (the battery). It's not going to help. (*Doug is creating a short circuit*.)

Doug: (*Defensively*) Well, that creates heat and heat creates electricity. (*He does not heed Tameka's advice and continues to try to stick the wire into the space at the top of the battery*).

Tameka: It (the wire) needs to be in the middle (of the metal part of the bulb). Metal to metal. (Video transcript, 10/16/07)

As we saw here, more often than not, the groups rebuked Tameka's and N'Lisha's efforts and, by the end of the unit, these two girls' interest in finding quick solutions and sharing them waned. Incidentally, Doug fashioned himself and got recognized by others as a “science person” and, in this class, science people got the answers without help from classmates, especially those who were not viewed by others as science people. Our interpretations here are supported by Doug's thoughts about “sharing” in his end-of-year interview:

Even if we don't tell anybody like right away, if we are doing a group thing and we have different discoveries, we don't just—We do—It's not—We're not keeping it *secret*. We just don't tell anybody about it until Mrs. Sparrow knows everybody is done and Mrs. Sparrow says you can share what we discovered with the class. That's like the only time. It's not really like keeping a secret. It's just waiting for the rest of the class to get done.

Doug, a White boy in the privileged position of being considered and considering himself “scientific,” drew a much different picture of sharing than N'Lisha, who told us in the end-of-year interview that the “smart” kids withheld information from the “other” kids. If the “smart” kids had the answer, they kept it secret. Further, Doug seemed to explain here that scientific investigation is conducted in the service of discovering and constructing knowledge on one's own, holding those discoveries and knowledge private until whole group debriefs, and then displaying the knowledge for the teacher.

Sharing Scientific Ideas and Tools in Ms. Wolfe's Class: What Did It Look Like?

Ms. Wolfe:	[W]e don't do ‘turns’ in science.
Heidi:	So, did you make that explicit? How did you get them to start [sharing ideas] with one another? Do you have an idea of how it came about?
Ms. Wolfe:	Um, how'd I do it? I don't—it's just never—sometimes it's not acceptable to work all by your little lonesome self, and we do talk about that … When they're together, they are expected to be working toward the same cause … I don't want them taking turns. I don't want them trying ideas by themselves … [W]hen you're working together, you both need to be able to tell me what question you're thinking about, what you're doing, and why you're doing it.

This exchange occurred after Heidi (first author) asked Ms. Wolfe about the norms card statement “We share scientific ideas” in our end-of-year interview. She described sharing practices in her classroom (i.e., “I don't want them taking turns”) as the antithesis of the ways it played out in Mrs. Sparrow's class. This meant that there was less competition to individually test one's ideas and more collective investigation. For example, the following interaction occurred during an activity early on in the electricity unit, where students explored the various ways to light multiple bulbs in a single circuit.

Alejandro:	**We** need a complete circuit
Jasmine:	Oh it (the bulb) does work. I think.
Linda:	The other one doesn't light though.
Alejandro:	Something's wrong.
Jasmine:	That's because **you're** using one wire and this one isn't touching. Wait.

Stop. **I've** got it. (*Takes hold of materials from Alejandro*.)

Alejandro: Why doesn't that one work?

Jasmine: Because for one, there's only one battery and this one's trying probably—

Linda: Try another battery.

Jasmine: Ask Ms. Wolfe if **we** can have one more battery.

Alejandro: I think **we** need another (inaudible).

Jasmine: I think **we** need another battery.

Alejandro: I think **we** need to take off this.

Jasmine: **We** need another battery. Let me see.

Jasmine: **I'm** wondering if this thing (light bulb) is dead or not. Wait. Wait, Alejandro. Let me check this, 'kay? (*She shakes the bulb near her ear, presumably to listen for a broken filament rattling*.)

Jasmine: How many wires are **we** supposed to be using?

Alejandro: I think one. (Video transcript, 5/12/08)

During this interaction, the three students huddled around the tools. We note here that Alejandro and Jasmine were both initially more engaged with tool manipulation, while Linda initially only contributed verbal ideas and recorded the group's ideas in her science notebook. However, soon after this interaction, Ms. Wolfe came by and encouraged Alejandro and Jasmine to move the tools to the center of the table so that Linda also had access, which is an example of the ongoing teacher vigilance necessary to maintain these more collective normative scientific practices. The group continued to use the "we" language throughout the activity, and Linda began manipulating tools. Toward the end of the activity, when the teacher came to the group to check on their progress, Jasmine reported, "We got it to work for a second," framing their work as a group-level accomplishment.

This interaction is a telling juxtaposition to the small group interaction example from Mrs. Sparrow's class. Students shared their ideas and verbalized their thinking to work together to complete the circuit; the consistent use of the pronoun "we" demonstrates this nicely. They asked each other questions and repeated and/or took up one another's ideas. Yet, we still see threads of the turn-taking norm (i.e., dominant students trying to control the materials) making its way into this exchange. Jasmine, who tended to play a more dominant role in groups, grabbed the materials from Alejandro ("Wait. Stop. I've got it."). At the same time, she did not exclude others from her problem-solving strategies, and made attempts to involve others in the problem-solving by asking them questions ("How many wires are we supposed to be using?"), hedging a bit and/or recognizing her dominance toward the end of this exchange by using a friendly "'kay?" qualifier, and framing the group's work to the teacher as a group-level achievement ("We got it to work for a second").

As tends to be the case in most small groups, more assertive members attempt to control the ebb and flow of activity. It may be impossible to completely escape a turn-taking norm and the power struggles that come along with it. In this class, however, the "we solve problems*together*" norm was a worthy, if not stronger, counterpoint norm. One of the reasons for this was that Ms. Wolfe not only *expected* students to share tools and ideas; she *held them accountable* for doing so. Students *were obliged to* express their own ideas in small groups and *had to be* well versed in group mates' ideas.

Amy:	(asking teacher) Can **we** have another battery?
Ms. Wolfe:	Maybe if your partner (José) were here. Why do **you** want a battery?
Amy:	Because if **we** have three batteries, **we** are going to see if it's brighter than **our** two batteries.
Ms. Wolfe:	Do **you** predict that it will be? (*Amy nods her head to respond. Ms. Wolfe looks to José to explain*).
José:	Because if **we** tried it with two and it was like really shiny and when **we** tried it with one, it wasn't that shiny and that means that it gives it more energy.
Ms. Wolfe:	Good. Shiny is like my watch. You're talking about bright, brighter, brightest. Okay, try to use those words. (*She gives them another battery and moves on*.) (Video transcript, 4/25/08)

In this interaction, Ms. Wolfe held students accountable for understanding one another's ideas. Amy could not receive another battery until Ms. Wolfe was satisfied that both partners could fully explain why they need another battery. This excerpt also illustrates that the teacher alone did not determine the collective nature of scientific investigation. Students actively took up this meaning, evident in their pronouns "we" in response to Ms. Wolfe's pronoun "you." José's informed response demonstrates that requesting another battery grew out of their joint investigation, rather than out of Amy's sole investigation.

A further example that illustrates students holding *one another* accountable to share their thinking and to work collectively, even between groups, follows:

Jeremy and Alejandro are constructing a circuit using a switch.

Alejandro:	Oh my god that [light] is so bright.
Alejandro:	(*to someone else in a nearby group*) Look! Ours is really bright.
Student:	(*off camera, from another group*) It's not as bright as ours.
Jeremy:	Look at this—it's got a switch though.
Alejandro:	(*to Jeremy*) But how could we make it brighter?
Jeremy:	With more batteries.
Alejandro:	Explain.
Jeremy:	More batteries, less wire.
Student:	(*from the other group*) Why do you want to use less wires?
Jeremy:	Because the wires just make a longer place for the electricity to go and then that means that the electricity travels more and doesn't have as much strength.

In this exchange, we saw intra- and inter-group sharing. There was a bit of the competition between groups that we saw in Mrs. Sparrow's class (“It's not as bright as ours”; “it's got a switch though”) but, in counterpoint, they also asked questions of one another (within and between groups), holding one another accountable to explain their thinking (“Explain” and “Why do you want less wires?”). Because Jeremy was forced to share his thinking, his alternative conceptions about how electricity flows through a circuit surfaced. This norm of sharing ideas in small groups made for productive whole-group discussions, as alternative conceptions developed in small group were brought to the fore more often, acknowledged by the teacher as worthy of scrutiny and lively discussion.

In countless ways, Ms. Wolfe held students accountable for critically listening to and jointly constructing knowledge with their partners in small groups and whole groups. She questioned students about their group mates' ideas and had a policy that “both people, or all three people [in a group] are responsible for being able to share out [to the whole group]” (Interview, 8/13/08). She often privileged the voices of the quietest students—“I'm gonna pick the least talkative person who probably has not stood up for themselves and say, ‘The group can't start until this person tells me what the plan is”’ (Interview, 8/13/08). She recognized that, without this scaffolding, nine- and ten-year-olds' small groups “turn into ‘I'll do my thing and you do yours”’ (Interview, 8/13/08). To further scaffold successful sharing in small groups, Ms. Wolfe had explicit conversations with children about how to use physical space in groups.

Ms. Wolfe:	We do talk a lot about what would make—when two people work together, does it really make sense that I'm over here, and you're over there. We talk a lot about physical space.
Heidi:	Ok, yeah you do.
Ms. Wolfe:	Um, we talk about partner reading and what makes sense, and where would we put it, and is it better that we're shoulder to shoulder, or is it across, or is this a better [position]? We do talk—because they don't know how to do that.

We often witnessed various students sharing their insights with Ms. Wolfe as she circulated around the room, and sometimes she would gently place both hands on the child's head, physically turning their head to face the direction of their group mates, with the implicit message, “Don't tell me, tell your group.”

Ms. Wolfe also scaffolded the collaborative problem-solving and increased accountability for every students' active engagement with strategies like “think, pair, share” (i.e., think about some questions or an answer to this problem, share it with a partner, then share it with the whole group) in whole group discussions. Before breaking out into small groups, she and the children would brainstorm ways to “appropriately” work in groups, pertinent questions to ask one's partner, and polite ways to correct a partner's mistake. Though this kind of intensive scaffolding took time, she did it consistently (i.e., the excerpt below is from the end of the school year) and efficiently. For example:

Ms. Wolfe:	I'm going to put you in partners and you and your partner are going to partner read. How should you be sitting?

Several muffled responses, inaudible.

Ms. Wolfe:	Side by side. How are you going to know to take turns?

A couple of students say, “Paragraph.”

Ms. Wolfe: Which pattern? Give me the English words.

A few students call out various ideas, mostly inaudible on tape.

Ms. Wolfe: Every other paragraph. Okay. Like AB, AB. Another way to say that is every other paragraph or Jasmine, it sounds like you might sometimes prefer to do every other page. Of course, I'm listening for fluent reading. What do you do if your partner gets a word wrong? Do you correct them immediately?

Group: No!

Student: Count to ten.

Ms. Wolfe: Count to ten in your head. Let them try again and, of course, good readers always go back and?

Group: Reread!

Ms. Wolfe: Oh, thank goodness. Then if it's really stuck, you can help. Okay? But nobody likes to be corrected that minute, right? It's a little embarrassing and it's frustrating. (Video transcript, 4/23/08)

Ms. Wolfe came down fairly hard on students who did not hold up their obligation to be a “good group member” and consistently praised those who performed as good group members. For instance:

Ms. Wolfe: Excellent! Your partner is recording excellent observations. Do you have any observations?

Roberto: No.

Ms. Wolfe: No. Then that's unacceptable Roberto. Oh, Sanchez is on it! Good work. Nice partner work. (Video transcript, 4/11/08)

In part, Ms. Wolfe held them accountable for recording detailed observations and interpretations so that they could later share them with the group. Another example:

Ms. Wolfe:	Uh-huh. Can we try it—hey! Whoa. Freeze. Have you explained your theory to José?
Jeremy:	No.
Mrs. Wolfe:	Tell him.

Jeremy explains his theory to José in Spanish. (Video transcript, 4/11/08)

A third example:

Ms. Wolfe:	Oooh! What happened? Interesting. Ok, Amy make sure that José gets a chance too. Can I borrow your paperclip? Make sure Mira gets a chance too. (Video transcript, 4/10/2008)

This vigilant scaffolding and high expectations of being a good “partner” or “group mate” positioned science as a collective endeavor and “science person” as a good contributor, listener, and group member. The explicit and consistent discussions and modeling of what to do and say as a “good partner” increased the accessibility of science and science person.

Outcomes of the Collective Problem Solving and Investigation

In this class, *scientific investigation* meant trying out one another's ideas together; it was a collaborative endeavor. Not only did Ms. Wolfe's actions position scientific investigation in this way, students took up the promoted practices of science so that “doing science” in this class meant, in part, working with, sharing ideas with, asking questions of, and listening to a partner or group mates. We witnessed many instances when students raised questions about or explicitly referenced a classmate's ideas when expressing their own, such as:

Sanchez:	Yes. **We** also noticed that was not possible with just one or two magnets.
Ms. Wolfe:	Hmm.
Sanchez:	It was only possible with three magnets.
Ms. Wolfe:	That is interesting. What would you add, Christine?

Christine:	Well, **I kind of disagree with Sanchez**, because **me and Ramón** got six magnets to do that.
(About five minutes later in the discussion, Jeremy picks up this thread).	
Jeremy:	May I say something that I really [want to share]?
Ms. Wolfe:	Yes.
Jeremy:	**Like Christine was saying** that you could get it with **what Sanchez said** of magnets, I got it with less. I got it with one and two magnets.
Ms. Wolfe:	You mean when [the magnet] was vertical? Okay. That's a whole other interesting entity. Interesting. You did? Amy, I haven't heard from you.
Amy:	**I disagree with Sanchez**. Because **we** only used one and two magnets and **we** got about the same thing. There was only like a two or three difference [in number of paper clips attracting to the magnet].
Ms. Wolfe:	Okay. Well **Sanchez's definitely found a pattern** that he was able to prove. Now, something that you did could have been slightly different from what he did. But he was onto something and I thought that was interesting. Christine?
Christine:	**My group shared with Jasmine and Jeremy's group**.
Ms. Wolfe:	Um-hum. Very nicely, I might add, for **good teamwork**. Franco, eyes this way.
Christine:	And so, **we** used six magnets and it worked better when **we** used more magnets.

The next day's investigation centered on testing Sanchez's idea with a consistent protocol across groups, created in a class discussion. (Video transcript, 4/10/08)

This exchange, typical of debrief discussions in this class, is evidence for students taking up the promoted meaning of “science person” implied by the sharing practices. A *science person* shares scientific ideas with others, builds on and questions others' ideas, and contributes to the class's scientific knowledge. Science people disagree, but do so politely; “Scientists have polite words” (Interview with Ms. Wolfe, 8/13/08). Further, science people are patient about and active listeners of others' ideas.

No individual student owned *scientific knowledge*; it was jointly constructed. Notice in the above classroom discussion how often students referenced their trials and solutions as joint constructions—for example, “*we* also tried” and “*we* got the same thing.” Even though Ms. Wolfe labeled Sanchez's idea as an individual achievement (i.e., “Sanchez's definitely found a pattern”), Sanchez's idea actually became a reference point of discussion. Students problematized it to the point that the next day's activity became a collective endeavor for further investigation. In presumably an effort to minimize the “attacks” on Sanchez's idea, Ms. Wolfe praised Sanchez's thinking (“He was onto something, and I thought that was interesting”). In this example and in most every class discussion we witnessed, the normative sharing practices distributed responsibility, across the whole class, for constructing knowledge; “everybody's ideas [were] valid” (Interview with Ms. Wolfe, 6/27/07).

As we saw with the threads of competitive language and dominant students attempting to control the activities in earlier examples, students did not come to these practices easily. Ms. Wolfe used a lot of scaffolds and reminders to make these normative ways of sharing explicit and accessible for all students. She would “compliment it, compliment it, compliment it” whenever she saw or heard it (Interview, 8/13/08), providing recognition to those who successfully took up the practice and motivating those who struggled with the practice to work toward it. The fact that she consistently held students accountable for enacting sharing practices in these ways meant that students had strong opportunities to take up the practice, an important aspect of evaluating the accessibility of the practice (Gresalfi et al., 2008).

Sharing Scientific Ideas in Mrs. Sparrow's Class: What Was the Purpose?

Ethnographic studies of classroom cultures provide thick descriptions (Geertz, 1973) of everyday practices, but also make inferences about the *purposes* of those practices. In these next two sections, we examine the purposes of sharing scientific ideas in each class. In other words, we address the questions, “Sharing of scientific ideas to what end? What did the practice accomplish?” These questions help further define implicit meanings of scientific investigation, scientific knowledge, and scientific person promoted in each classroom.

There were two primary purposes for sharing scientific ideas in Mrs. Sparrow's class: (1) to get to “the” answer; and (2) to prove *to the teacher* that you were thinking, but more importantly, knew the answer. These purposes were implicit; Mrs. Sparrow incorporated many strategies representing what we know as good teaching practice.[2] For example, students debriefed their findings of the daily investigations in whole group settings at the end of the class periods. Mrs. Sparrow called on and elicited ideas from many students during these discussions. She did not give up on students if they could not immediately articulate their answers, and she did not only call on the students she expected would have the right answer. On the face of it, these practices seemed fairly equitable. A lot of students contributed to the class discussion, expressed their scientific ideas publicly, and were excited enough to volunteer answers. Mrs. Sparrow generally recognized many different students' ideas positively (e.g., “Good answer,” “I see what you're saying,” “Interesting,” “That's a good thought,” “Thank you, Christopher and Doug. Thank you Valerie. Luka. Excellent.”). However, this feedback was a somewhat generic recognition; she thanked them for speaking up, but did not necessarily provide specific feedback about the nature of their contribution as it related to the construction of the scientific idea. Further, as is evident in the example below where students discussed the purpose and results of a magnet activity, the discussion about the concept or idea generally halted when someone produced the “right” idea in the “right” way.

Student: [We were supposed] to figure out how many spacers you could put in and how many washers you could put in to see how strong the magnets are.

Teacher: Ok.

Student: We were trying to see how strong the magnets were attracted together.

Teacher: Ok.

Student: The more spacers, the less washers.

Teacher: Let's stick to the more space between the magnets, the—?

Student: Less attractions!

Teacher looks to the next student with hand raised.

Student: When there's more space, the weaker the magnet. It's not as powerful.

Teacher: Well not the magnet, but the—?

Student: Force!

Teacher: So the more space between the magnets, the weaker the—?

Student: Force.

Teacher: Very good. We will continue talking about magnets next week. (Fieldnotes, 10/12/07)

If students did not express the right idea in the right way, the teacher provided the answer, sometimes without recognizing students' correct reasoning. For example:

Mrs. Sparrow: Who knows what a source is? If I'm going to tell you that this battery or this D-cell is a source for electrical energy, what is a source? Jake?

Jake: A source is something that you use, like an idea.

Mrs. Sparrow: Okay. Celia, what do you think?

Celia: It's kind of like of a scale, a skill.

Mrs. Sparrow: A skill. How is this [*holding up battery*] like a skill?

Celia: Oh, never mind. I thought you said like something like a resource.

Mrs. Sparrow: Well, it's different from a resource. A source is where—?

Mike: It gives off stuff sort of and it stores things.

Mrs. Sparrow: A source is where something comes from. What comes from a D-cell? (Video transcript, 10/16/07)

In this example, Jake begins by confusing one meaning of a "source" (i.e., an origin) with the meaning used in their language arts curriculum (i.e., a reference, like the dictionary). Mrs. Sparrow does not explicitly recognize this difference, but Celia does and follows Jake's line of reasoning—a source is like a "resource." Celia's and Jake's answers are logically connected to one another and even to the scientific meaning of "source" in this case (i.e., an electrical source can be a resource), but Mrs. Sparrow does not recognize these connections and repeats the question. Mike picks up with a more direct connection to the desired definition, explaining that a source is something that "gives off stuff and stores things." Mrs. Sparrow does not explicitly recognize his connection, but instead provides students with the "proper" definition.

In instances like these, students' very logical and sound intellectual contributions do not get recognized. And, while it is certainly easier for us to notice these opportunities for recognition while we analyzed the data versus doing so in the midst of the rough and tumble of practice (Crawford, 2007), the consistent glossing over of students' varied intellectual contributions to privilege the “right” answer, phrased in the “right” way, resulted in a somewhat inaccessible definition of legitimate *science knowledge* and *science person*. Those who had access to the proper (technical) scientific vocabulary and a firm grasp of Standard English were recognized more often than those who did not.

Mrs. Sparrow:	What kind of circuit? We talked about it …
Selena (ELL student):	Serious.
Mrs. Sparrow:	Not serious. (*Waits*)
Student:	Series. (*Said in a corrective tone, to Selena*. *Selena puts head in hands, seemingly embarrassed*)
Mrs. Sparrow:	(*Nods head*) Series circuit. (Video transcript, 10/31/07)

Students took up these definitions of science knowledge and science person (i.e., these became shared cultural meanings, not only the teacher's meanings). Though sometimes subtle and/or lighthearted, students corrected others' vocabulary (as above) or laughed lightheartedly with the teacher about another students' use of informal versus technical vocabulary. Another example:

Mrs. Sparrow:	How could you use only one battery, one source, to light up one bulb so they both light brilliantly? Christopher, what do you think?
Christopher:	Get stronger wires and stronger little connector thingies.
Mrs. Sparrow:	Connector thingies? (*Everyone laughs*.)
Christopher:	The things that plug the light bulbs. (Video transcript, 10/31/07)

As was the case in many class discussions, in this example, the purpose of sharing was to prove *to the teacher* that one knew the answer or was at least thinking about the answer. The students spoke out publicly, but Mrs. Sparrow was the implied audience. Given what we know about the prevalence of the Initiate-Respond-Evaluate (IRE) discourse pattern (Mehan, 1979) in classrooms, this is not entirely surprising. However, Mrs. Sparrow actually tried to break out of the IRE discourse pattern by validating, at least in a general way, each student's contribution (e.g., “Interesting,” “Ok,” “I see”). We came to call this “not quite IRE” interaction pattern the Initiate-Respond-Hunt-Evaluate (the IRHE pattern)[3] because it became fairly clear that, while Mrs. Sparrow genuinely appreciated students' attempts, she was “hunting” for someone to come up with the right answer. The student with the “right” answer often got more validation, leaving the students who were uncertain a little less confident in sharing their answers. We saw that with Celia in the above quote (e.g., “Oh never mind …”), and we see it here with Kisha: For example:

Mrs. Sparrow: Okay. So what do we use batteries for?

A student responds, but inaudibly.

Mrs. Sparrow: Sorry?

Kisha: **Never mind**.

Mrs. Sparrow: No. Don't say never mind. Keep going with your thought.

Kisha: One of the things—(*hesitates*) what do we use batteries for?

Mrs. Sparrow: I don't know. **You tell me**.

Kisha: I don't know.

Mrs. Sparrow: What do we use batteries for?

Kisha: Everything. (Video transcript, 10/16/07)

During whole group discussion, those less fluent with vocabulary and science concepts would often “pass” to another student if they were stuck. It was commonplace to ask another student to help out, rather than persist with one's ideas. For instance:

Mrs. Sparrow: Who can further explain this whole snowman idea? That's what some of you named it. (*She chuckles*.) What was the snowman idea? Tameka, you were working with that group.

(*Speaking of constructing parallel circuits with wires, bulbs, and batteries in a “snowman” configuration*.)

Tameka:	Making more than one pathway so they won't have to share the same electronics.
Mrs. Sparrow:	Making more than one pathway. So. My goodness. That's huge. When we're making more than one pathway, what does that mean, Tameka? What is a pathway?
Tameka:	Where, uh, where, uh—(*She seems to be struggling*.) I don't know. (*She rolls her eyes and looks hesitant. She looks around the room*.)
Mrs. Sparrow:	Do you need help? Pick a friend who can help you.
Tameka:	Pass to Caitlin. (*She picks Caitlin to help her out, and Caitlin answers*.) (Fieldnotes and video transcript, 11/2/08)

The above quotes not only illustrate Kisha's and Tameka's discomfort with and their eventual abandonment of their initial ideas, but also the nuanced nature of the way the "prove it to me" norm may have marginalized less confident students. Again, Mrs. Sparrow used great questioning strategies here—she persisted in probing Kisha's and Tameka's understanding (demonstrating high expectations) and gave Kisha and Tameka the responsibility for coming up with an idea. The "prove it to me" norm actually resulted in many students using evidence-based reasoning, sometimes unsolicited by the teacher, by the end of the first semester (Fieldnotes, 11/2/06).[4] But, as we point out below, this purpose of sharing (to prove to the teacher that you have the answer) promoted less inclusive definitions of scientific investigation, scientific knowledge, and scientific person. Further, the same students were often called on to help out those who struggled, making ever more visible their rank in the classroom hierarchy.

Outcomes of the "Prove it to Me" Purpose of Sharing

These normative ways of sharing scientific ideas implied that the purpose of *scientific investigation* was to come up with "the" answer; it had a discrete endpoint. Though Mrs. Sparrow elicited many scientific ideas from many students and validated each student's idea, the student with the "right" answer, phrased in the "right" way received the highest validation. This was problematic in that the student who publicly shared the correct answer may have been drawing on peers' previously stated ideas (those who did not quite have the correct understanding) to be able to express her/his more robust and correct understanding.

In this way, sharing was a relatively risky endeavor for those uncertain about the answer. Further, this norm placed responsibility for "proving it" on the shoulders of individual students, while the teacher's role was that of arbiter of the ideas. Inevitably, some students' ideas got legitimized more often than others (i.e., those mentioned as "the science kids" by the girls of color in end-of-year interviews and/or those consistently chosen to help out the students who struggled in whole group question and answer sessions), leaving an eventual recognizable division between the science kids and the “other” kids. As was the case for the turn-taking norm, the “prove-it-to-me” practice implied that *scientific knowledge* was individually owned. A *scientific person*, therefore, was the one who most often produced the answers. Our interpretations here are supported by students' descriptions of “smart science people” in end of year interviews as those who held the most knowledge and most often produced the right answers. For example:

Mandy:	I would say—I think I'm kind of a science person. And I think Emily's kind of a science person, too.
Julie (author):	Why do you think you are science people?
Mandy:	Well, because that's something that we both are interested in—And like Emily, she's usually raising her hand and I'm usually raising my hand. We're usually giving the right answers. And like when I usually answer and I'm sure when Emily usually answers, it feels like, ‘Wow I got that right,’ and it feels like a real scientist.
Emily:	[I felt most like a science person] when I was in the science lab, we were doing this unit and I could answer most of the questions. (She chuckles.)
Julie (author):	So, when you answer most of the questions, you feel like a science person?
Emily:	Yeah!

Sharing Scientific Ideas in Ms. Wolfe's Class: What Was the Purpose?

Students shared questions and ideas to demonstrate their scientific curiosity, one of the most prized aspects of being scientific in Ms. Wolfe's classroom. For example, when discussing their interpretations of the teacher's expectations of them, students said:

Sanchez:	[We have to] think other thoughts. We have to think outside the box.
Amy:	And ask good questions. (Lunch interview, 5/8/08)

Asking questions was indeed common practice in whole group and small group activities. “We asked tons of questions … that was more how I guided science” (Interview, 8/13/08). Here is an example of a typical debrief of an experiment:

Ms. Wolfe:	Who can name a question that we still have about this experiment? What question do we still have, Diane?
Diane:	How do the two paperclips stick when they're not touching the magnet?
Ms. Wolfe:	Very good. What question do you still have Ramón? (*No response*) You don't have any? All of yours are answered? (*Said with a little admonishment*)
Ramón:	Yeah.
Ms. Wolfe:	Okay. Bianca, what's your question?
Bianca:	Why do some paperclips fall that touch the second one?
Ms. Wolfe:	Good question! (*Ramón puts his hand up*). Ramón.
Ramón:	Why doesn't it stick back when like when you stick the paperclip there (shows with hands) the magnet, is still sticking but when you take it off and you stick it and it doesn't stick back?
Ms. Wolfe:	Why did it hold on for just a minute? Good question, so when you take the magnet away, sometimes some things continue to stick, don't they? Good point! Jeremy, a question that you still have?

(*Teacher continues to elicit questions from three more students before she gets to Jasmine's question*)

Ms. Wolfe:	One more question from Jasmine. Y'all are full of excellent observations that have caused lots of questions.
Jasmine:	How did other people get more than five to stick to the magnet and the magnets are probably equally powerful?
Ms. Wolfe:	Good question. Would you like to hear an answer to that one?

Several: Yeah!

That question became the next day's investigation. (Video transcript, 4/11/08)

Prior to the above interaction, the teacher elicited multiple students' observations made during their small group investigation, and then, as shown above, she moved on to elicit multiple questions ($n = 8$) that arose out of their observations. In this interaction, everybody's questions were valid, and Ms. Wolfe held every student accountable for being curious, for asking questions. She gently admonished Ramón, who initially claimed to have no questions, and who, instead of giving up, soon came up with a question that met with Ms. Wolfe's approval (thus positioning himself in ways that aligned with the promoted meaning of science person). Jasmine's question became the impetus for the next day's investigation. Implied in this interaction and the many others like it is that the purpose of scientific investigation is not necessarily to arrive at a “correct” answer, but to ask more questions—a practice accessible to all students. In this kind of science, not all questions will be answered. Thus, reasons for scientific investigation and sharing are to make careful, informed observations that prompt new questions.

Outcomes of the “Sharing Observations and Questions” Norms

This classroom's norms began with the premise that all children, regardless of formal background knowledge and academic experiences, are inherently curious and science is a way to tap into that natural curiosity and everyday experiences. “Everybody is ready for each topic. Maybe not starting at the same place, but it's applicable to everybody. All of my kids may not be ready for two-digit multiplication, but all of my kids are ready to tackle electricity because everybody's had experience with it” (Interview, 8/13/08). Ms. Wolfe encouraged careful observation by “valuing all the small pieces of things that people notice” (Interview 8/13/08). And, in prompting them to share their observations and questions, she encouraged them to think scientifically. Even hesitant and shy students and/or students who struggled academically took up the observation and question-sharing practices. As Ms. Wolfe said:

They have to engage, they have to be able to have conversations, they have to practice their interpersonal social skills … there's the give and take, the leader, the follower, everybody's ideas are valid. Kids who see things differently have a chance to express that. (Interview, 6/27/07)

Frequently, Ms. Wolfe had to balance her need to “move on” with the curriculum with students' enthusiasm for sharing their observations and questions. In one lesson (1/14/08), students begged her to let them continue listing their questions because they wanted to show her that they came up with many more questions than the goal they set as a group ($n = 23$ questions) before the activity. They came up with over 30 questions; sharing took over 15 solid minutes of instructional time! Students' participation here, and Ms. Wolfe's willingness to diverge from her initial plan, demonstrates question-sharing practices as group-level accomplishments.

Different students' observations and questions became the impetus for the entire group's future investigation, which validated the worth of the questions and emphasized *scientific knowledge* as social and generative. *Scientific investigation* did not always have a specified endpoint; it opened up opportunities for more questions and investigation. As Ms. Wolfe said, “I don't feel like I emphasized at all [that] investigations had to be successful, but that we learned something and made observations that we could use for our next investigation” (8/13/08).

These sharing practices also broadened meanings of *science person*, someone who makes careful, insightful observations and asks good questions. Ms. Wolfe explicitly tried to contest the “know-it-all” (Interview, 8/13/08) science student prototype because she said it limited “risk-taking … and learning from mistakes” (8/13/08). She did not want students to “only produce work they're sure about—that is gonna be absolutely perfect” because if the “perfect” work was the norm, “the first time they don't know [an answer], that's gonna be the type of science they don't like” (8/13/08). Ms. Wolfe did not place pressure on them to share one right observation or idea, and as a result, all students could and were expected to perform themselves scientifically.

I never had a student who was truly uncomfortable with sharing … it's a safe environment, and I think it's just an expectation they see as something that they're gonna do … And I think the fact that we're not critical … there's really no fear. We don't criticize people's thinking … We write questions, and we compliment that … So I don't think it's fearful. (Interview, 8/13/08)

Students named and recognized this broader meaning of “science person,” social nature of scientific knowledge, and generative nature of scientific investigation in end-of-year interviews.

Angela (author):	Why do you say these students are good in science?
Jasmine:	Amy's always asking questions.
Shelby:	And Cesar has good reasons.
Jasmine:	When Alejandro works in partners, he works really well, he's always concentrating and he doesn't get off track. He stays on the same thing that he's supposed to stay on. And he pays attention during class. Like if he gets a partner that doesn't pay attention a lot, he'll explain what you need to do. And like if you're not paying attention he'll make you pay attention.
Jasmine:	Amy's always thinking about different experiments to do. I mean, that's all she thinks about in science. Lots of different experiments.

These broadened cultural productions of science person beyond the “know-it-all” prototype made for a more accessible science for a wider range of students.

Discussion

The Equity Problem, Revisited

Underlying Assumptions about, and Solutions to, the Problem

Few would argue about the existence of an equity problem in science education. However, we argue that the problem is nearly always positioned in such a way that leaves unexamined the underlying assumptions about the nature of the problem, the implied solutions to fixing the problem, and/or the taken-for-granted definition of success. For example, if the equity problem gets framed as solely an “achievement gap” problem, the assumptions are that students have certain deficits to overcome before they achieve in science. The implied solution to the equity problem framed this way, then, is to improve students' deficits (i.e., improve their knowledge and skills). Success means improved achievement, as measured by standardized test scores.

The above line of reasoning assumes that fixing the problem involves “changing” those from nondominant groups. Others have framed the equity problem in ways that emphasize the need to change school science (see Brotman & Moore, 2008, who argue similar points about the evolution of the gender problem framing in science education literature). For example, as the *National Science Education Standards* (1996) suggest, one problem with traditional school science is that it has historically positioned students as receivers, rather than producers, of knowledge. The implied solution to achieve “science for all,” in this view, is to improve science curriculum and/or pedagogy in ways that position students as knowledge producers. Even these reform-minded perspectives, however, often measure success with improved achievement and perhaps improved inquiry skills. In other words, the reframing of this problem as a “school science problem” versus a “student deficit” problem does not, alone, reframe what counts as success.

A third framing of the problem similarly points to school science's curriculum and instruction as problematic, but does so to highlight the ways it leaves out and/or marginalizes students from nondominant groups. This framing implies a slightly different solution; we need to change science curriculum and/or pedagogy so that it includes the experiences, worldviews, learning styles, funds of knowledge, and/or interests of students from diverse backgrounds. The implied success with this framing, however, still may not shift beyond measuring improvement in science achievement and skills, and perhaps more positive science attitudes.

In uncovering the assumptions underlying common framings of equity, we argue for reframing what counts as success. Our study demonstrates that changing students' knowledge, skills, and even attitudes through engagement in reform-minded curriculum should not be the only criteria for success. The girls of color in Sparrow's class who ultimately disaffiliated knew science, could engage in school science's practices, and claimed to like science, but did not define themselves as “smart science people.” Furthermore, they actively disaffiliated themselves from those they considered smart science people.

Ours is not the first study to demonstrate this distinction between liking science and affiliating with it. A recent study by Archer et al. (2010) examining 10- to 14-year-olds' declining science interests found that though the 10- and 11-year-olds reported enjoying science (i.e., they found it fun, exciting, and interesting), they identified many reasons why they did not affiliate with the promoted meaning of “smart science student” that were linked to race, gender, and class (e.g., being an “egghead”; being brainy vs. athletic). The authors argue that it is important to “consider how we might bridge the gap between children and young people's everyday identities (those that are experienced as desirable, authentic, and conveying status within their daily fields of interaction) and the identities and messages conveyed by school and ‘real’ science” (pp. 636–637).

Reframing the Equity Problem

We argue that reframing the equity problem requires a more holistic, sociocultural approach that takes seriously the *meso-level structures*that, over time, organize, sort, and alienate students. One way to identify and address the equity problem in this re-framing is to examine closely the normative scientific practices that help define implicit meanings of “science” in a given setting. Doing so positions school science as socially and culturally produced in everyday practice; it raises questions about the science that students are held accountable to know and do. Is this science viable, relatable, and potentially relevant to/for students from wide-ranging backgrounds and experiences? Is this a science that privileges one right answer at the expense of acknowledging the logic and reasoning involved in problem solving? Does this science value the creativity and critical thinking involved in asking insightful scientific questions? Is the scientific knowledge produced in the classroom an individual achievement or are students given opportunities to collectively own the scientific knowledge produced in the classroom?

Our study emphasizes the relevance of these normative scientific practices for students' affiliation with science, for their views of themselves as “science people.” In these two classrooms, a practice as foundational as “sharing scientific ideas” involved very different participation structures (searching for and providing the right answer versus listening for and providing insightful observations and questions), scientific thinking (closed vs. generative), and obligations (turn-taking vs. productively exchanging ideas). These differences provided us with insight as to why certain students did not affiliate with or feel confident performing themselves as “smart science students.”

A second way to address the equity problem while considering a meso-structural lens is to critically identify and expand the subject positions afforded to students in school science (Olitsky, Flohr, Gardner, & Billups, 2010). Who are students obligated to be? In our study, students in Mrs. Sparrow's class were encouraged to be doers of science. This is an expanded subject position compared to that required by traditional school science, but one that still falls short to truly address the equity problem. In Ms. Wolfe's class, students were obligated to be collaborative producers of knowledge that would be used in service of future investigations.

Clearly, Ms. Wolfe's students' were afforded broader subject positions. Elsewhere, we discuss this finding in more depth, highlighting the ways the cultural and social norms of Ms. Wolfe's class enabled students to leverage their social identities in service of their scientific identities (Carlone, Kimmel, Lowder, Rockford, & Scott,2011).

Recently, others argued for similar solutions. For example, Calabrese Barton and Tan (2010) discuss equitable science classrooms as spaces where students can expand the roles they play, opportunities to negotiate their participation, and share authority. In their study, success was defined, in part, when tensions between what it meant to "be scientific" and what it meant to be an urban youth collapsed. Elsewhere, Calabrese Barton and Osborne (2001) argue that an equitable science education should position students not only as knowledge producers, but also as *users* of scientific knowledge. O'Neill (2010), too, makes a similar argument, describing equitable classrooms as spaces where students can cultivate a sense of ownership and agency, and develop identities in science.

Relatedly, a third way to identify and address the equity problem is to examine and define the processes by which knowledgeable and struggling students get defined, that is, the *cultural production of science student*. The concept of "normative science identity" is helpful here because it forces consideration of the norms students are held accountable to in order to be considered smart science students and also the opportunities for all students to access and perform those norms on a regular basis. In the two classrooms presented in our study, students were held accountable to different normative scientific practices, and there were uneven expectations of and opportunities to perform these normative practices in Mrs. Sparrow's class. This lens, in fact, troubles the notion of "natural" smartness (Gresalfi et al., 2008). Instead of asking, "Who's smart?," we ask "Who's being given opportunities to perform themselves as smart? Who takes up opportunities to perform as smart? Who gets recognized as being smart and why?" Melissa Gresalfi et al.'s (2008) work is helpful here, as they argue for researchers to examine competence not as an attribute of individuals, but "as an attribute of participation in an activity system … such as a classroom. In this perspective, what counts as 'competent' gets constructed in particular classrooms, and can therefore look very different from setting to setting" (p. 50). In our settings, there were indeed different definitions of competence, that is, students were held accountable to different norms to be considered competent.

A corollary implication here is that we must trouble the notion of "opportunity." What counts as an opportunity to perform oneself competently? For example, in this study, all students had opportunities to construct and share scientific knowledge in small and whole groups (i.e., hands-on, small group activities and whole-group debrief discussions were available options; they were major aspects of doing science in each classroom). However, those opportunities varied in terms of their strength and accessibility. The normative science identity lens refines the notion of "opportunity to learn," from considering it as a *chance* or *option* to examining the *obligations* to which one is held accountable to be recognized as competent. When considering the problem of equity, we might ask: Are all students held accountable to perform themselves competently? Are they given appropriate support and recognition to do so consistently? To whom are they held accountable? Not only did “competence” mean something different in Ms. Wolfe's class than it did in Mrs. Sparrow's class, Ms. Wolfe held all students accountable for performing themselves competently. In Ms. Wolfe's class, it was not acceptable for one group of students to speak up and carry the whole group conversation, to keep one's scientific ideas private, to monopolize the tools in small groups. An equitable science classroom, then, cannot be defined with the criterion that everyone has the chance to learn when the opportunity presents itself. Instead, our study implies that an equitable classroom is where all students are entitled, expected, and obligated to participate competently (Gresalfi & Cobb, 2006). Thus, we might shift from asking of classrooms the prototypically generic question, “Are all students given opportunities to learn?” to asking a more specific, demanding question like, “How insolent would a student have to be to resist (fail to take up) these norms? Are some students excused from performing themselves competently?” (M. Gresalfi, personal communication, April 10, 2007). When we consider the obligations students are held accountable to and the expectations for various students to meet those obligations, we can better understand why certain students come to affiliate and others disengage from promoted meanings of “science person.” Students in Mrs. Sparrow's class who did not affiliate with the promoted meanings of “smart science person” were highly aware of the classroom hierarchy and of the different expectations to perform competently. For example, in an end of year interview, N'Lisha said, “Some students are expected to share their ideas, but not everyone.” These different expectations may seem invisible to those more privileged, but are highly visible to those with less power.

Building the Equitable Science Classroom: (Re)creating Worlds of Science Learning

Reforming science education with a “science for all” core commitment is difficult for so many reasons and on so many levels. We have a relatively large body of literature that has helped identify a dizzying number of variables that affect the difficulty of reform; for example, teachers' knowledge, skills, and beliefs; policies that limit teachers' agency; testing pressures that limit time for meaningful science instruction; historically enduring meanings of schooling; students' resistance to more demanding roles; the science curriculum's relevance for a wide range of students; misunderstandings about the nature of science; and on and on. This study, however, points to an overlooked, but substantive aspect of the difficulty of reform.

When examining science education reform with a cultural lens, we do not view the endeavor as a matter of solely tweaking political and institutional variables or actors' behaviors, values, and beliefs. Instead, we view the process of reform as (*re*)*creating worlds*. Using existing cultural resources, both material and symbolic, a group develops habitual ways of “doing” school science, applies similar values and meaning to practices over time, and implicitly positions certain students as more able than others (Holland, Lachicotte, Skinner, & Cain, 1998; Wortham, 2006). School science learning is, in a sense, a figured world, a “collectively realized ‘as if’ [realm]” (Holland et al., 1998, p. 49) that disciplines people, shaping and getting shaped by people's thoughts, values, feelings, and actions. Figured worlds are sociocultural realms “of interpretation in which particular characters and actors are recognized, significance is assigned to certain acts, and particular outcomes are valued over others" (Holland et al., 1998, p. 52). For example, a figured world of prototypical school science learning is often one where only those who have access to and find interesting out-of-school science experiences (summer camps, after-school programs, museum visits, dinner table conversations about science and nature) and resources (science tradebooks, computer programs, television shows) get defined as "smart science students." Over time, actors become more and more familiar with the practices and rules of a figured world and eventually author themselves within (or against) the world. The figured worlds of school science learning, set within larger historical and institutional contexts, are places where students become intimately acquainted with issues of power and inequity, and with the hierarchies of race, class, and gender. Science adds another dimension of power, imbued as it is with historical associations of elitism and inaccessibility.

These hierarchies, power relationships, positions, and rules that govern a figured world are continually recreated in everyday practice with existing cultural resources; thus, we are always recreating worlds. However, all of this is to say that it is much easier to "do school science," to (re)create figured worlds of science learning, in ways that reproduce the status quo. The figured world concept is helpful to conceptualize reform because it is a means to understand "historical subjectivities, consciousnesses and agency, persons (and collective agents) forming in practice" (Holland et al., p. 42). Reform-based, equitable school science represents the creation of a new figured world that requires different configurations of cultural resources, new norms and practices, new meanings of competent participant, and new subjectivities and sensibilities. When we conceptualize reform as world-building, we acknowledge it as an ongoing achievement. The digressions from prototypical practices, norms, values, and subjectivities in reform-based, equitable science make the processes of "doing school science" evermore visible compared to the taken-for-granted practices of prototypical school science that have made sense to and structured the participation of generations of actors. This new figured world requires constant maintenance, vigilance, persistence, endurance, and commitment. Practices, roles, and positions do not come to actors automatically as they might in the prototypical figured world of school science learning. In this study, we saw the constant maintenance of the more equitable "sharing scientific ideas" norm in Ms. Wolfe's classroom. Left unattended, students sometimes enacted similar kinds of turn-taking, equipment-domination, and competitive "sharing" practices as they did in Mrs. Sparrow's classroom. These practices are not surprising given the renewed emphasis on individualism in today's US society and schooling. Ms. Wolfe continually modeled and scaffolded appropriate sharing practices and consistently elicited students' contributions as to what those "appropriate" practices should be through class discussions (e.g., recall her discussion of how to appropriately sit and help peers before they did the partner reading activity). This does not mean that Ms. Wolfe's actions alone accounted for the more accessible and equitable sharing practices; students successfully learned and took up the promoted practices, playing a role in their continued success.

In this article, we highlighted the ways the normative practice of sharing scientific ideas promoted *scientific investigation* as a collaborative, generative endeavor, *scientific knowledge* as shared and jointly constructed, and *science person* as someone who builds on and questions others' ideas, contributes to the class's scientific knowledge, and someone who asks good questions and makes careful, insightful observations. Taken together, these meanings may not sound too radical or transformative, but the world-building work to realize these meanings was indeed significant. What if there existed a world of science learning where one's race, ethnicity, or socioeconomic status did not affect one's affiliation with science? Ms. Wolfe's classroom provides a glimpse into what that figured world might look like.

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1 It might be tempting to explain Ms. Wolfe's success with her English Language Learners to the bilingual instruction. Of course, this was a large part of why and how she was able to connect with her students. But, as we show in the article, the bilingual instruction was not the only reason why she had such success cultivating science affiliation for a broad range of students.

2 Our worry here is that readers will view these snapshots of Mrs. Sparrow's classroom and come to the conclusion that (1) she was an incompetent teacher and/or (2) her classroom norms were *so obviously* not representative of good practice that, of course, this was not an equitable classroom. Neither is the case. Mrs. Sparrow is an outstanding, caring teacher who went above and beyond what was expected of her. It took us approximately 2 years of iterative analysis to identify the ways her classroom norms enabled affiliation to science for some and inhibited affiliation for others. Indeed, the story we tell here ignores the success stories in Mrs. Sparrow's class—for example, Emily, the girl who, before this class, was too shy to speak up at all in class and who, over the course of the school year developed a confidence and a love of science that persists 3 years later. We are highly conscious of the ways scholars' portrayals of classrooms can reproduce problematic histories between the academy and public schools (Carlone & Webb,2006). Therefore, we strive to portray Mrs. Sparrow's classroom as *nuanced*, rather than representative of a falsely dichotomous “best practice” or “poor instruction.” At the same time, we are similarly aware of the overly rosy picture portrayed of reform-based science in some science education literature—portrayals that, for example, leave unquestioned the implications of a well-managed, more-or-less well enacted reform-based science for students from groups who have been historically under-represented and oppressed in/by science.

3 Thanks to research team member, Jean Rockford, for coming up with this terminology.

4 Students' evidence-based reasoning may not, however, have been as sophisticated as that called for by Bell and Linn (2000). The students relied on data to support their claims, but frequently did not include warrants or backings.

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