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Rethinking Diversity in Learning Science: The Logic of Everyday Sense-Making

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Abstract: There are many ways to understand the gap in science learning and achievement separating low-income, ethnic minority and linguistic minority children from more economically privileged students. In this article we offer our perspective. First, we discuss in broad strokes how the relationship between everyday and scientific knowledge and ways of knowing has been conceptualized in the field of science education research. We consider two dominant perspectives on this question, one which views the relationship as fundamentally discontinuous and the other which views it as fundamentally continuous. We locate our own work within the latter tradition and propose a framework for understanding the everyday sense-making practices of students from diverse communities as an intellectual resource in science learning and teaching. Two case studies follow in which we elaborate this point of view through analysis of Haitian American and Latino students' talk and activity as they work to understand metamorphosis and experimentation, respectively. We conclude with a discussion of the implications of this new conceptualization for research on science learning and teaching. © 2001 John Wiley & Sons, Inc. J Res Sci Teach 38: 529–552, 2001

National standards and goals for reforming science education have asked for more and more academic rigor in learning and teaching complex subject matter (American Association for the Advancement of Science, 1993; NRC, 1996). Embedded in the science education community's reform efforts is a belief that rigorous standards backed by quality curricula and effective teaching—often identified as a form of inquiry—will translate into robust learning and high levels of achievement for all students. Yet it is not at all clear how this goal—to eliminate the achievement gap separating low-income, linguistic, racial, and ethnic minority students from more economically privileged students—will be accomplished.

There are many ways to understand the achievement gap. In this article we offer our perspective. First, we discuss in broad strokes how the relationship between everyday and

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Everyday and Scientific Sense-Making: Perspectives from Science Education

The term *scientific* is commonly used to denote a sphere of human activity characterized by special qualities: rationality, precision, formality, detachment, and objectivity. This view is broadly held in society at large, in schools, and even by some scientists themselves. The term *everyday* is commonly used to denote another, opposing set of qualities: improvisation, ambiguity, informality, engagement, and subjectivity. The presumed differences between scientific and everyday activity are often framed as sets of dichotomies, with the left-hand term in the pair being the privileged, scientific one, the one seen as representing a cognitive ideal: precise versus imprecise language, logical versus analogical reasoning, skepticism versus respect for authority, and so forth. But what is the status of these dichotomies as descriptions of human experience?

Within the field of science education, different traditions have emerged that revolve around the examination of the relationship between everyday and scientific knowledge and knowing. In one tradition, the relationship is viewed as descriptive of differences in the knowledge, knowing, and language use characteristic of ordinary people and of scientists. In a second tradition, the dichotomy gives way to an articulation of dimensions of continuity between ordinary people and expert scientists. Each of these views is at bottom concerned with understanding how students learn science and how best to teach science. However, each represents a different way of framing the relationship between everyday and scientific sense-making, and as such each carries different implications for learning and teaching in science. We briefly discuss each.

In one tradition, everyday experience and ways of talking and knowing are seen as discontinuous with those of science and as barriers to robust learning. This tradition assumes, and reports evidence to support the view, that children's everyday ideas and ways of knowing and talking are largely different from and incompatible with those of science. Two main variants of this tradition are research on misconceptions and studies of cultural congruence. For example, misconceptions research holds that students' everyday ideas are strongly held, may interfere with learning, and need to be replaced with correct conceptions (Clement, 1982; McCloskey, Caramazza, & Green, 1980; McDermott, Rosenquist, & van Zee, 1987; Viennot, 1979). Studies in this tradition argue that misconceptions, say, about force and motion, arise from students' prior learning, often from their day-to-day interaction with the physical world (Clement, 1983; McCloskey, 1983). Thus, everyday experience is viewed as a principal source of the educational problem.

Similarly, recent studies of cultural congruence catalogue what the authors describe as the incongruence between the habits of mind and language and other interactional practices of students from certain language minority groups (e.g., Haitian Creole–speaking communities) and those valued in national science standards. They suggest further that these habits of mind and interactional practices may impede students' learning in science (Lee & Fradd, 1996, 1998; Lee, Fradd, & Sutman, 1995), as in the following:

> In teacher–student interactions, both teachers and students from diverse backgrounds bring with them ways of looking at the world representative of the environment in which they have been reared. These habits of mind or ways of knowing may or may not be compatible with scientific habits of mind or ways of knowing typically associated with scientific discourse. . . . [I]nteractional patterns within a language and culture group may be incompatible with scientific practices as taught in the mainstream. For instance, the nature and practice of science involves the use of empirical standards, logical arguments, skepticism, questioning, criticism, and rules of evidence. These practices may be incongruent with cultural interactions that favor cooperation, social and emotional support, consensus building, and respect for authority. Scientific practices to encourage critical, creative, and independent thinking may also be incongruent with cultural interactions in which information is given to learners by authority, be it a teacher or a textbook. (Lee & Fradd, 1996, p. 274)

In this view, differences in the social, cognitive and linguistic practices of particular linguistic or ethnic minority groups from those of the "mainstream" are conceptualized as potential barriers to student learning and achievement in science, as outside those characteristic of science. It is argued in particular that whereas teachers may be successful in supporting these students' engagement by establishing culturally congruent ways of participating in school science, such as through respect for authority or with emotional support, such classroom norms may in fact be "inconsistent with the norms of discourse and task engagement in science" as outlined in national science education standards (Lee & Fradd, 1996, p. 285).

A second tradition of inquiry in science education takes a different view. It focuses on understanding the productive conceptual, metarepresentational, linguistic, experiential, and epistemological resources students have for advancing their understanding of scientific ideas (Clement, Brown, & Zeitsman, 1989; diSessa, Hammer, Sherin, & Kolpakowski, 1991; diSessa, 1993; Hammer, 2000; Lehrer & Schauble, in press; Minstrell, 1989; Nemirovsky, Tierney & Wright, 1998; Smith, diSessa, & Roschelle, 1993). This work does not assume a simple isomorphism between what children do and what scientists do; rather, it views the relationship as complex and taking a variety of forms: similarity, difference, complementarity and generalization. Clement et al. (1989), for example, introduced the notion of "anchoring conceptions" to describe cases in which students' understanding aligns well with physicists' understandings and how to use these to develop "bridging analogies" to assist students in applying their understanding in multiple contexts. Minstrell's work (1989) exemplifies a similar valuing of students' ideas as a conceptual resource in developing their understanding of physics, as when he uses students' understanding of springs to build an understanding of passive forces (e.g., the force exerted upward by a table on a book). diSessa et al. (1991) investigated another aspect of children's cognitive resources in understanding motion by focusing on what they called "metarepresentational expertise," a flexible and fluid ability to generate, critique, and refine representational forms.

In addition, children most particularly disadvantaged by approaches based in a dichotomous view are those whose everyday ways of knowing and talking are seen as being the furthest from those traditionally valued in school science or even in national standards. Recent research concerned with this issue has documented the various ways in which poor and minority children's ideas and ways of talking and knowing are related to those characteristic of scientific communities (Ballenger, 1997, 2000; Conant, Rosebery, Warren, & Hudicourt-Barnes, in press;

Gee & Clinton, in press; Michaels & Sohmer, 2000; Rosebery & Warren, 1999; Warren, Pothier, Ogonowski, Noble, & Goldstein, 2000; Warren & Rosebery, 1996). In our work in bilingual and in economically and racially heterogeneous classrooms, for example, we have come to view scientific sense-making as encompassing a varied complex of resources, including practices of argumentation and embodied imagining, the generative power of everyday experience, and the role of informal language in meaning making. We have found, for instance, in these classrooms that students, even as young as first grade, employ accounts of everyday experience not merely as a context for understanding scientific phenomena but as a perspective through which to see and encounter heretofore unnoticed aspects of a given phenomenon, to create possibilities for both seeing and encountering the phenomenon differently (Warren et al., 2000). Furthermore, we have found, it is particularly students who find themselves otherwise marginalized in school science who are able to call on these resources in ways that prove productive for them as well as for typically academically successful students (Ballenger, 1997; Rosebery, 2000; Warren et al., 2000).

These findings are buttressed by recent research in social studies of science and history of science, which has described the intricate intertwining of conceptual, imaginative, material, discursive, and experiential resources in scientists' work (Biagioli, 1999; Fox-Keller, 1983; Gooding, Pinch, & Schaffer, 1989; Goodwin, 1997; Jacob, 1995/1987; Latour & Woolgar, 1986; Lynch, 1985; Ochs, Jacoby, & Gonzales, 1996; Rheinberger, 1997; Root-Bernstein, 1989). These studies, in their detailed analysis of the everyday work and talk of scientists, support a greatly expanded view of scientific practice, one which goes beyond emphasis on hypotheticodeductive reasoning and theory-building, everyday experience as a form of misconception, and informal language as inadequate to the task of precise description, explanation, and modeling.

In this article we present two case studies which illustrate what we have learned about the heterogeneous nature of scientific sense-making and about the intellectual power of the sense-making resources of poor and minority children through careful study of what these children do and say as they make sense of scientific phenomena. We focus on two aspects of scientific sense-making not often included on lists of desirable practices or habits of mind: everyday language use and embodied imagining. We explore each through analysis of the ways in which children from diverse linguistic and cultural traditions develop biological arguments on one hand and design and evaluate experiments on the other.

Case Studies

Our inquiries into science learning and teaching in bilingual and heterogeneous classrooms have begun with the same kind of question asked in social studies of science and ethnographic inquiries of classroom learning and teaching: What is going on here? We have asked this question of communities of students learning physics and biology, of communities of teachers and educational researchers doing science, and of these same teacher-researcher communities exploring students' ideas (Ballenger, 1997, 2000; Conant et al., in press; Hudicourt-Barnes, 2000; Rosebery & Warren, 1998a,b; Rosebery, Warren, & Conant, 1992; Warren & Rosebery, 1995, 1996; Warren, Rosebery, & Conant, 1994). In this mode of inquiry, we have tried not to take for granted standard formulations of the differences between scientific language and practices and those in use in our everyday lives, such as around the dinner table, in church, in the gym, and on the playground. We have explored, directly and indirectly, what people—children, teachers, educational researchers, and scientists—say and do as they learn or do science. We have believed, following the history of this kind of research in literacy, that what counts as appropriate language or practice in these contexts and for these purposes needs to be investigated, rather than assumed; that forms of language, such as precise description or arguing from evidence, or practices, such as experimenting or modeling, have not been adequately described in relation to either everyday practices or scientific practice within professional communities. This perspective has led us to address the following questions in our research:

1. What are the sense-making resources (e.g., intellectual traditions, social practices, experience, ways of using language) that students from ethnically, culturally, and linguistically diverse communities bring to science?
2. What is the nature of the relationship between the sense-making resources of children, particularly children who are not excelling in science, and those characteristic of science? How do we—researchers and teachers—make this relationship visible? What role can the resources that children from diverse communities bring to school play in science learning and teaching?

In the following two cases, we focus our attention on the ways in which students make sense of scientific phenomena to accomplish particular purposes in science. In the first case, Everyday and Scientific Language, we focus on the language used by a Haitian student to understand metamorphosis as a particular kind of change or development. In the second case, The Logic and Practice of Experimentation, we focus on the ways a Latino student approached the problem of designing an experiment to explore ants' preference for darkness or light.

Case I: The Logic of Everyday Languages[1]

Taking on a scientific worldview is generally conceptualized as a movement toward greater precision, abstraction, generality, and overall power in both thought and language (Halliday & Martin, 1993; Lemke, 1995). However, in exploring the linguistic and intellectual traditions with which children from diverse communities approach science, we have come to see that the relationship between the language and language practices which are used in everyday life and those which are used in science is rather more complicated. In this section we explore this relationship by looking closely at a student doing science in what we might call his first language, that is, the unschooled language of his home.

What do we mean here by "first language"? There are at least two possible ways to think about the role of language in relation to children's ability to think and talk scientifically. We want to make reference to both. First, there is a child's national language. In the classroom we discuss, the students' first language in this sense was Haitian Creole (HC). HC is a language that has developed within the past 300 years among people brought to Haiti from Africa as slaves. These people did not share a common language, because they were from various linguistic groups in Africa. Thus, the vocabulary of HC is almost entirely based in the vocabulary of French, the colonial language. The grammar, however, is variously ascribed to influences from West African languages and/or to influences from what is sometimes called a bioprogram, that is, a hypothesized universal grammar that is arguably a part of human linguistic inheritance. HC has not been used in schools in Haiti until recently and is rarely used for academic or other formal purposes. For this reason, it is often said that HC and other Creole languages and nonstandard dialects of English as well do not contain technical language, lack scientifically precise terms, are concrete rather than abstract, are better used for expressing emotion than for making rational arguments, and, more generally, that there is something always nonformal about the way these languages express things.

The second meaning for "first language" we intend here is in reference to what Heath (1983) termed "ways with words." Ways with words refers to patterns of language socialization and use. Individuals may speak the same national language, and yet linguistic and social practices such as storytelling or argumentation may typically occur in different contexts in their lives, may occur to different extents, and may even assume different forms. Thus, children come to school with varying levels of familiarity with the ways words are used in school, e.g., what kinds of stories are appropriate and when, what kinds of arguments are allowed, what the significance is of the various shifts in vocabulary which are typical of talk in science.

The students discussed in this case were Haitian immigrants who had been in this country for less than 3 years. They all spoke HC. In many cases, their parents had had little opportunity to receive much education in Haiti; some were not literate. The children themselves, who were in fifth through eighth grade, had sometimes had only irregular schooling before they came to the United States. By many accounts, as students of science these children were disadvantaged by their first language in two senses: first, because their national language, HC, is not considered by many as adequate to the construction of a high level of scientific understanding; second, because the ways of talking, explaining, arguing, and presenting information that they heard and engaged in at home are seen by some as far from the academic or schooled form of language used in the science classroom.

In this case, we focus on how one student, Jean-Charles, used his first language in both senses to deepen his understanding of metamorphosis. To begin, we present an account of a science discussion in which Jean-Charles participated to give a sense of the heterogeneous styles of participation used by students in this classroom and also to show Jean-Charles' thinking at this point. We ask: What are students learning in a context where stories, jokes, and challenges are allowed? How did this use of everyday language practices support their science learning? Then we turn to an interview that took place some time later in which Jean-Charles reconsidered some of the same issues. Here we ask: In what ways is Jean-Charles using what he already knows about language as a tool to explore what he is seeing about insect metamorphosis?

Background. At the time of this study, Jean-Charles was in the sixth grade. He was a quiet child, respectful and diligent at school. He was solemn, not a storyteller or joker like many of his classmates. He spoke softly and it frequently took him a long time to begin to speak; the class often had to wait while he formulated his thoughts. He was judged to have difficulty organizing language in both HC and English, and because of this received extra help in school from a learning disabilities tutor. His drawings, on the other hand, were detailed, full of shading and texture, and greatly admired by his classmates.

The story of the ways in which Jean-Charles and his classmates came to participate in and talk about science began with their teachers. It is a long story; for the purposes of this article, we briefly describe particular aspects of the classroom here. The class was a multigrade, bilingual class, cotaught by two teachers, Pat Berkley, an English as a Second Language teacher, and Sylvio Hyppolite, a Haitian Creole bilingual teacher.

Pat and Sylvio's respect for and knowledge of their students' first language in both senses was grounded in a number of experiences, two of which they located in the Chèche Konnen teacher seminar (Warren & Rosebery, 1995). Pat reported that the opportunity she had had to "do science" in the seminar had had a profound effect on what she heard as "scientific" in the classroom. As a student, Pat had not experienced success in science; as an adult, she had thought of herself as unscientific. In the teacher seminar, however, she had been able to study snails and leeches on a long-term basis, learning much about them through her observations and drawings.

She found that her questions, which to her sounded silly and unscientific, were taken seriously in the seminar and contributed in significant ways to her own and others' understanding. This opened up for her the possibility that her way of thinking about the world might have value in learning and teaching science. As a result, she determined to take her students' questions seriously, especially those that sounded silly or unscientific.

For his part, Sylvio reported that the teacher seminar had given him opportunities to investigate new participation structures in science, structures that encouraged his students to use their everyday language practices, including modes of arguing and storytelling. As part of the seminar, he had watched a videotape of another teacher's class in which Haitian students vigorously debated one student's claim (Warren & Rosebery, 1996). Sylvio recognized the tone and rhythm of the discussion, which were familiar to him not from his classroom, which was quiet and contained at the time, but from street corner discussions in Haiti and from his students' arguments and discussions on the playground (Hudicourt-Barnes, 2000). As familiar as he was with the energy and skill that many Haitians put into argumentation, he had not thought of this as a resource for learning in science. After watching the tape, he resolved to include this kind of talk in his science class.

Together, Sylvio, Pat, and the children created a structure which they came to call "science circle." Science circle was a time to hear students' questions, for students to read aloud from their journals, to share observations, to try out theories, argue claims, and the like. The focus was on the student to elaborate or clarify what he or she meant. The teachers talked relatively little. When they did, they asked genuine questions. Science circle became a place where students talked to students, challenged each other, asked each other to clarify, even joked and told stories. It was at times a rollicking event. At all times, science circle was a context in which the students and teachers were able to draw on their familiar, everyday ways of characterizing, organizing, theorizing, and arguing about the phenomena of the natural world.

Negotiating Meanings for Change. The first example we present in this section took place in a science circle[2] after the students had spent some weeks watching mealworms move through stages of metamorphosis. Manuelle had been reading aloud to the class from a text in English about metamorphosis. After reading how much the larva eat before they turn into pupa, she asked her classmates somewhat rhetorically: "Why, if people eat and eat, don't they change their skin, don't they transform, the way insects do?" Sylvio, who was teaching this lesson, asked the students to comment on her question. The book was put away and a science circle ensued.

One child responded that human skin does peel, presumably connecting this to the way larva shed their skin. Manuelle returned: "But we don't transform." Fabiola said, "God did not create us like insects." She evidently meant that that is why we do not transform. Raoul brought in basketball: "If you play basketball, you get dirty; when you bathe, your skin comes off with the dirt." He was suggesting that, like the larva, we, too, change our skin. Marianne responded to this claim: "It's not all people who do that." She got up to demonstrate how slowly some old people walk, implying that because they do not play hard, they do not get dirty and then change some of their skin while bathing. Jean said that he had learned on television that your skin rubs off inside your clothes. Stefan, a new student, made a general statement, declaring: "People and animals aren't the same thing." He was in a space with Fabiola, perhaps: God did not make us like that.

Jean-Charles then addressed a response to Manuelle and Manuelle's initial question:

> Manuelle, skin changes. It's like, the larva, when it was inside the egg, you, like when you were inside your mother's stomach. It's like, when you were a little baby, when you were

> born, when you were a little baby, you had hardly any hair. Didn't that change? Don't you have hair?

At that point, the children exploded. Manuelle said that not all babies are born without hair. Marianne wanted to distinguish growth from change: You grow, you do not change, she told Jean-Charles. Jean-Charles responded to Marianne on the question of change versus growth: ''When you were a baby, your eyes were closed.'' His implication was that clearly they were no longer closed; thus, she had changed. Joanne appealed to Sylvio as she pointed out that Manuelle at that moment and Manuelle as a baby did not look the same; Manuelle had changed. Manuelle listened to this and then stood up to exclaim, ''Do I change my skin like this, *vloop, vloop*?'', pretending to unzipper her skin and climb out of it.

What was the intellectual substance of this conversation? What was being argued and debated? We see this conversation as a negotiation over what the term *change* might mean in the context of experiences with insects. These students were asking whether there is one kind or more than one kind of change. Would one word do or did they need more than one? What distinctions should they make? They were negotiating which distinctions matter in this context. Certainly, Jean-Charles was right and Raoul, too, with his basketball analogy: We all change—in some contexts it might even be appropriate to talk about the metamorphosis of a young child into an adult. But what were the crucial features of change in this conversation, with these intentions? The crucial features vary depending on what you want to figure out. In their attempt to understand their mealworms' life in relation to their own, the children created a need to sort out a particular version of what matters in describing insect and human development.

When the children first focused on changing skin, Manuelle reminded them that she was thinking also of transformation, that is, change of form. In the end, with her *vloop vloop*, we do not know whether she was referring only to the movement of a larva out of a whole skin, or, because she had been continually reminding the students that transformation is a part of this, too, she also had some view of movement from, say, pupa to beetle in mind. In any case, she was on the side that there are differences between what these insects do and what humans do.

Some children claimed the opposite. They had learned that humans do slough off their skin playing basketball, as Raoul suggested, or inside their clothes, from sunburn. Thus, they argued that in this case human processes and insect processes were the same: Humans change skin, insects do, we all do.

Jean-Charles represented perhaps the broadest usage of change. His opening claim was: ''Manuelle, skin changes.'' He went on to give an example which was a change of form: The larva is like the embryo. He then added growing hair, another sign of change which, he seemed to be claiming, was comparable in some way to the changes of metamorphosis. He pointed out to Marianne, when she challenged him by saying, ''We grow, we don't change,'' that her eyes were open now but they probably had not been at birth. Jean-Charles seemed to want to use ''change'' to refer to any number of differences and developments, such as height, more hair, open eyes as well as the development from a larva to a pupa, from embryo to newborn. According to Jean-Charles, all animals change over time: insects and humans. He seemed to see metamorphic change, changing skin, and hair growth as all significantly the same.

Metamorphosis is, as some children suggested, a particular kind of change, a series of distinct stages; it is not a kind of change that is noticeably gradual and continual, like growing over periods of time, as Marianne mentioned. Rather, it crucially contains discontinuous stages—*vloop, vloop* and it is over and done. It follows a reliable pattern; it does not differ from individual to individual like hair growth might, or the ability or desire to play basketball, as a number of children argued. Although at this point not all the students agreed on how the terms should be used, they were getting at the basis for the use of the terms *grow* and *develop* in biology, the former with its reference to continuous change and the latter with its reference to reliably patterned transformation from one discrete stage to the next.

In this rollicking talk, the children brought their everyday reasoning, ways of talking and making sense into contact with the issues in science that they were exploring. They used their familiar ways of talking as resources to help them as they thought out loud. Specifically, the students spoke in their first language, a Creole language not known for its scientific vocabulary. They also talked to each other and in a manner that is more often associated with social situations outside of school. There were jokes and disagreements, and references to religion as well as basketball, bathing, and old people. There were physical demonstrations and dramatic enactments, such as Manuelle's *vloop vloop*, and Marianne's slow old-people walk.

From our point of view, this conversation demonstrates how the children's everyday ways of talking and thinking supported multiple ways to begin to talk about growth and development. Their familiarity with each other and their deep knowledge of their first language allowed them to joke and tease on the one hand, and probe meanings and imagine change in insects and in people on the other. We do not see these everyday ways of talking and theorizing as in opposition to scientific ways, or even as fully distinct from them. They seem clearly to be resources that support deep intellectual engagement. To consider how Jean-Charles continued to think about these issues, we look at an interview which took place several months later.

Distinguishing "Grow" and "Develop." In the prior discussion, Jean-Charles had proposed a broad use of the term "change," which covered everything from the stages of development to the growth of hair and the opening of eyes. In this interview excerpt, he describes a beetle. We include the original HC here as well as its English translation because we want to make a point about how he is using the grammar of his first language to help him distinguish the kinds of change in the phenomena in front of him.

> Li gen yon pakèt de chanjman. Premye chanjman an se lè l te ti bebe li vin gran epi, dezyèm chanjman an li vin tounen yon "pupa." Twazyèm chanjman an epi li vin tounen yon "beetles."
>
> *It has a whole bunch of changes. The first change is when it was a baby it got bigger, then, the second change it turned into a pupa. The third change then it turned into a beetle.*

Jean-Charles is saying that the beetle goes through a lot of changes. The larva grows, then it gets bigger. Then, after a certain period, it turns into a pupa and then a beetle. He calls all these phenomena chanjman/changes, reminiscent of his use in science circle of a broad definition of change that includes everything from metamorphosis to growing hair. However, here he seems to be making a distinction he had not made before. Notice the words he chooses to make this distinction: *vin(i) gran* means to *become big*, and he uses this for growth. *Vin(i) tounen* includes the idea of becoming (vini) and of turning into or transforming (tounen), and this he uses for *change to another form*. He uses *vini* as a part of both meanings and alters the second term to distinguish the kinds of becoming. There are other HC words he could have used, such as *grandi*/grow for growing bigger, *transfòme*/transform for turn into. Remember that Manuelle used *transfòm* to begin the conversation we explored earlier and Joanne, among others, used *grandi* in that same conversation. However, by including *vini* in both phrases, Jean-Charles preserves a sense that, whereas both "become," one becomes big and one becomes something else. Thus, the sense of contrast as well as similarity is represented iconically in the phrases he chooses: one part common to both phrases, one part different. Having sorted into two terms these kinds of change, that he perhaps once regarded as essentially the same, he chooses by the words he uses to mark the sense that they are both aspects of the same thing.

Haitian Creole happens to have in its syntax the capacity to place many verbs next to each other in what are known as serial verb constructions. Thus, Jean-Charles can say *vini tounen*, literally "become turn into," and be grammatically correct in HC, although this construction sounds odd in English. We propose that Jean-Charles makes use of this capacity of HC syntax to explore his developing sense of aspects of change. As a result of its historical usage, HC may not contain a lot of technical terminology in biology but, like any language, the potential for clarity is there, as Jean-Charles demonstrates.

Later in the same interview, of his own volition Jean-Charles switches to English, and in speaking about ants he uses the English terms *grow* and *develop* to work further with these same two aspects of change.

> The eggs develop, um, they, the eggs become, um grow, the eggs growing bigger bigger bigger bigger till it's, um, develop and when it's finished it could be a queen or a worker.

Here he again develops a creative use of terminology, this time in English, to distinguish the types of change he sees within the processes of one organism. He starts by saying the eggs develop, then backtracks to say they grow, which they do not, although the larva inside, which can be seen much more readily, do. The eggs (i.e., larva) grow "bigger, bigger, bigger." They do this "till it's, um, develop and when it's finished it could be a queen or a worker." When he uses "develop" here, he is concerned with radical changes of form. He uses what must for him be a past participle, "develop[ed]," focusing on the over-and-doneness of the change, which he marks again in the next phrase, "when it's finished." Thus, he doubly marks the sense that the focus in development is on the end point. This was Manuelle's "*vloop vloop*" point: Some change is quickly over and done with, "*vloop vloop*!" In contrast, when he is referring to continuous growing he uses a present participle with a comparative and repeats the comparative three times, "growing bigger bigger bigger." The focus here is clearly on the sense of the continuousness, not on the end point; the sense of ongoing process is almost onomatopoeically presented here with the repetitions of "bigger." Again, we have the sense from the way he puts these terms together that in English, as in HC, Jean-Charles is particularly interested in his sense of the way these terms contrast with each other, the distinctions that they make together. He began, during the whole-class discussion, by articulating an undifferentiated view of change; now he has these two aspects, central ones for biology, existing in some sort of defining contrast.

Rethinking Language Use in Science. Often, and especially in the science classroom, scientific terms are seen as part of the framework of an explanation. They refer to each other in the edifice of theory that they jointly build. For example, it is difficult to understand tension without compression and a theory of forces is implicit in fully understanding them both. We think Jean-Charles is using, first of all, the language he knows best, HC, and then later on English, as a tool to map out the territory of growth and development in a similarly broad and contrastive conceptual landscape. He develops his awareness of these terms in relation to each other, with definitions that he seeks to refine. During the science circle, he articulated an undifferentiated view of growth; later in the interview he showed a deeper and elaborated understanding of these two aspects of growth, central concepts in biology. He moved from an unexamined everyday usage to a view which suggests an awareness of language itself. Although Jean-Charles is labeled as a special education student, a bilingual student with particular difficulties with language, here he demonstrated a creative and subtle way of working with words and meanings. He used Haitian Creole, and his then far from complete knowledge of English to construct ways to think with language about differences in meaning between *grow* and *develop*.

Languages are enormously flexible tools. There seem to be few limits to the ways in which someone who is thinking hard and feels the freedom of his well-known ways with words can find to make them work. A view of everyday language as unscientific and as contrasted with the precision and specificity of scientific terminology does not do justice to how human beings use language to think and to learn. It seems to us, however, that this is the way most schools and society in general tend to think about everyday language. A view of vocabulary or of language learning in science that focuses on appropriate production of particular terms obscures the living complexity and generativity of real language use. This example and others like it in our corpus have challenged us and our teacher collaborators to allow students to talk about their experiences using the full range of their linguistic abilities. It has further challenged us to examine carefully what the children are doing with their first language—in both senses—rather than to assume that jokes or personal experience or everyday words lack intellectual substance or are outside what we think of as rightfully scientific.

Case II: The Logic and Practice of Experimentation

Most studies of children's scientific reasoning have used constrained experimental tasks to assess how well children's reasoning conforms to a canonical view of experimentation as a method for identifying and controlling variables, or as a syntax of rules and strategies for making valid inferences (Klahr, Fay, & Dunbar, 1993; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn, Schauble, & Garcia-Mila, 1992; Schauble, 1996; Schauble & Glaser, 1990). In those studies, children's reasoning was examined through tasks which involved them in identifying causal and noncausal factors operating in a multivariate context. The students' challenge was to ascertain the effects of various manipulable features designed into the task (e.g., a boat's weight, size, sail size, sail color) on an outcome (e.g., speed of the boat). Thus, the tasks used in these studies privilege logical inference, or hypothetical deductive reasoning, as the ideal of scientific reasoning.

Although this psychologically based line of research has proven enormously productive, we approached the study of children's experimental reasoning from a different angle. We designed fairly open-ended tasks in which experimentation is approached more as an exploratory process—of constructing meanings for emergent variables—than a process of logical inference through which one identifies variables and uncovers relationships already designed into the experimental setup (cf. Rheinberger, 1997). Assuming an ethnographic stance, we carefully observed what children do in these situations and how they make sense of the problem before them. In our observations, a different picture from that found in the psychological literature emerged of the sense-making resources children bring to the practice of experimenting and how they learn about it as a knowledge-making practice.

In this section we examine the sense-making of a fifth-grade Latino student as he and two other students designed and evaluated an experiment to see whether ants prefer darkness or light. We also discuss how what he did expanded our notion of what counts as scientific reasoning. Thus, in contrast to the psychological tradition of inquiry into children's scientific reasoning, which has asked to what extent children's experimental reasoning approximates a logic of inference presumed to characterize the thinking of scientists, we pursue a different set of questions here: What did this child do as he engaged in this design task? What resources—linguistic, conceptual, material, and imaginative—did he draw on as he developed and evaluated his designs? How does our close examination of what he did bear on questions of children's scientific reasoning, of the nature of experimentation as practiced by scientists, and of what counts as scientific thinking?

Background. This case is drawn from a fifth-grade class in a transitional Spanish bilingual program in an urban school. The students investigated the behavioral ecology of ants over several months. An integral aspect of the children's work was the configuration of various ant habitats to create a suitable environment for sustaining ants, and ongoing discussions of conjectures and inferences that were either suggested or supported by the ants' behavior in each habitat. As we and the teachers observed and interacted with the children around this work, we noticed several characteristics which struck us as outside conventional descriptions of scientific reasoning in experimental contexts. The children seemed, for example, to want to imagine themselves into the ants' world and argue possible knowledge claims, against the constantly changing background of experimental designs. Our own growing wariness of taken-for-granted distinctions of everyday and scientific ways of thinking led us to take a closer look at the work the children were accomplishing. In the process we became convinced that they were engaged in something significant, albeit unfamiliar to us, that was worth exploring in greater depth.

Here, we examine the work of one student in the context of an interview, as he coped with the problem of constructing darkness—that is, of making distinctions among sources and degrees of darkness within the world of the experiment he was creating to make claims about ants' preference. We discuss the ways in which this student and others we interviewed expanded our understanding of the sense-making resources students bring to experimental situations. Furthermore, we discuss how the focal student's work and reasoning expanded for us the conventional view of experimental reasoning itself as a form of logic to one of a multifaceted practice in which one builds and imaginatively inhabits worlds to explore and argue possible knowledge claims.

In class, the students used techniques adapted from E.O. Wilson to construct environments suitable for studying and maintaining ants: plastic containers housing test tubes (surrogate tunnels) which held water, cotton packing to keep the water in, and aluminum foil wrappers (to simulate darkness). In these environments, they closely observed and documented various aspects of ants' behavior, social organization, and life cycle. They read and discussed texts on the subject as well. In the context of their work, the students, under the guidance of their teacher, Ms. Hernandez (a pseudonym), variously set up plastic containers to explore ants' preference for darkness or light, moist or dry soil, and their territoriality. These were undertaken more as observational studies than experiments per se, but involved along the way a variety of configurations and comparisons, including at times variations on the Y-tube design, an old but still used experimental method for seeing under controlled laboratory conditions what an organism will do, how it will behave, and what it will like.

All of the students spoke Spanish at home. Approximately half had high-level mastery of English, having lived most of their lives in this country. A couple of students spoke little English, having come to the United States from their native countries just before the start of the school year. Ms. Hernandez, herself Latina, was bilingual. She and the students used English as the predominant language of instruction, but Spanish was used freely when needed and was highly valued.

The discourse of the classroom reflected Ms. Hernandez's concern with integrating learning in science and literacy. She demanded a rigorous standard of definition and description, likewise a rigorous standard of evidence and evaluation. If, for example, a student claimed to see a fight between two ants, she was pressed to delineate exactly what she saw, including its sequence, which was then often compared with other, similar behaviors for verification. If a student suggested configuring the ant boxes in a particular way, he was made to justify the design. Typically students' observations and claims were collectively shaped and then used as resources in the group's subsequent work (see Eggers-Piérola, 1996, for a detailed discussion of this classroom's learning culture). The students thus had a great deal of experience observing ants and their behavior, configuring containers to explore how the ants might respond, and making, justifying, and challenging knowledge claims. There was little if any explicit discussion in class of experimental practice in terms of variables, controls, and experimental inference, strictly defined.

Constructing Darkness. To explore our sense that students were doing and saying things which seemed outside conventional descriptions of scientific reasoning, we interviewed students in groups of two or three. In school but outside of class we asked them to design an experiment to explore ants' preference for darkness or light, a question that had come to concern them as they observed ants in their class. The children brought with them a strong sense that ants preferred darkness, based on their various experiences with ants. Nevertheless, they engaged the question with considerable earnestness.

We focus on the discourse and work of one student, Emilio, but will make reference to the other two students who were interviewed with him, Juan and Yolanda. Over the course of the 40-min interview the students generated several designs to address the question of ants' preference for light or darkness. Much of their work focused on configuring materials such as wrapped and unwrapped tubes, soil, and so forth, within the space of an empty plastic container to create contrastive conditions of darkness and nondarkness.

Two staff members, Costanza and Mark, interviewed the students. Costanza was a participant observer in the children's classroom. After being introduced to the task, the students were asked whether they thought ants prefer the dark, as many students had maintained in class. All three agreed that they did. When asked what made them think so, however, they offered different views. Emilio, who typically was not a vocal member of the class, held that ants were always in the dark, that given the choice of a wrapped tube or an unwrapped tube, they consistently selected the wrapped tube. Juan supported the same claim, that ants prefer darkness, differently: ". . . when we put dirt in there, they—they were a little bit walking around but almost all of them were under the dirt, in the darkness." He imagined the dirt through the ants' experience, as an interior darkness, that is, the darkness an ant experiences by being under the dirt. Yolanda, initially shy, agreed with Juan. Emilio, when asked, agreed as well that ants like to go under the dirt because it is dark under there.

The children were then asked what they would do if they had to design an experiment to prove that ants prefer darkness to light. In front of them they had a large, empty plastic box. Emilio initially proposed connecting two boxes, following the model used in their class. In one, he would put dirt and a wrapped tube, and in the other an unwrapped tube only (Figure 1, Design 1). The two-box design proved technically impossible because there was no means available to connect them, so Emilio and Juan proposed new designs (Figure 1, Designs 2a and 2b). Emilio essentially replicated his first design, placing the two tubes, one wrapped and the other unwrapped, in opposite corners of the box (Design 2a). Juan, commenting on Emilio's design, proposed a modification: they should put in "something like metal" to divide the box

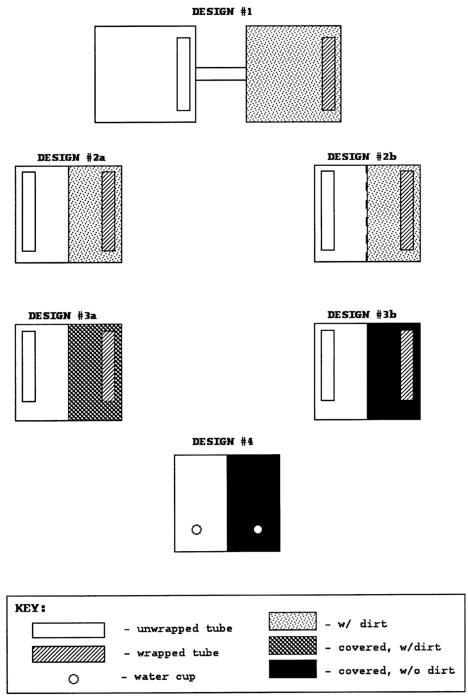

Figure 1. Sequence of students' experimental designs.

into two halves (Design 2b). One half would include "a little bit of dirt . . . with a water tube wrapped," whereas the other would include no dirt and an unwrapped tube. He would then look to see whether the ants "try to go this way, to this side," toward the side with the covered tube and dirt.

Costanza, referring to Designs 2a/2b, asked how they would know "whether it's the dirt or. . . the darkness, then?" Emilio responded immediately with a proposal to cover the side with the wrapped tube and dirt, in effect creating an encompassing or unambiguously "dark side" ("so it could be dark"), thus further complicating the picture. Juan agreed with this proposal.

This new design led Costanza to refocus her question:

> Costanza: . . . Now with the dirt or without the dirt?

This seemed a pivotal moment for Emilio and Juan. A long pause ensued. The boys gazed at one another. Emilio spoke first, but we cannot make out on the tape what he said. Then Juan spoke, suggesting that they should retain the dirt. Emilio disagreed:

> Emilio: It should be without the dirt 'cause maybe they'd (only)[3] like the dirt then.

Both Costanza and Mark asked him to repeat what he said.

> Emilio: That it should be without the dirt because maybe they (will/only) like the dirt. That's the reason why they're going over there.
>
> Costanza: Uh huh.

Mark: So you mean that they might like the dirt not because it's dark there but just 'cause they like dirt. [Emilio shrugs shoulders, nods yes.] Is what—that your idea?

Emilio: Maybe to keep warm because they (go under it).

What is going on here? We see Emilio positioning himself both inside and outside the ant habitat he is designing. In designing a material habitat with which to manipulate and observe ants' behavior, he has also envisioned, from the inside of this world, how its various material elements might be experienced by the ants. Like Juan before him, who imagined ants "in the dirt, under the darkness," Emilio, in analyzing the situation in light of Costanza's questions, has imagined how the ants might react to the presence of dirt and what that might mean in terms of their preferences. He has imagined the ants "going over there"—that is, into the dirt "maybe to keep warm. . . . " The world he has imagined is in this sense a lived-in world, one which he, the experimenter, enters imaginatively to experience it as an inhabitant of that world might: What might be so appealing about the dirt to an ant? What is dirt to an ant? How might an ant experience the dirt? We refer to this practice of inhabiting phenomena to see or feel or experience them from the inside as embodied imagining.[4]

Emilio's imagining from inside the experimental world is interwoven with a larger purpose, that of evaluating from the outside how ants might experience dirt in relation to a knowledge claim about their preference for darkness. His imagining is thus inextricably coupled to an evaluative stance he assumes toward his experiment, as a source of evidence for making knowledge claims. As he inhabited this world, he was at the same time thinking through the consequences of dirt for his claim about ants' preference for darkness. He became newly concerned with how the presence of dirt might interfere with any claims he would be able to make regarding ants' preference for darkness; he came to see dirt as potentially possessing a quality other than darkness which might appeal to ants. Thus, as he created an encompassing darkness, he also imagined the ants in action and what their experience of dirt might be. For some reason other than darkness, warmth maybe, they might be drawn to the dirt. On this basis, he moved to eliminate dirt from his design.

This interplay of inside and outside perspectives continued as Emilio considered other possible designs. The question of whether to include dirt persisted, with Yolanda wanting to add dirt to both sides of Emilio's design. Emilio addressed this issue:

Emilio: If we—if we put dirt we should put dirt on both sides, but if—we *should not* put dirt (and) on no side(s) just put the thing in [using his hand to indicate a divider] and one side covered and the tube with the thing over it and a tube not with the thing over it.

In response, Costanza asked him why he would put dirt on both sides. He explained, following his earlier reasoning, that if they only put dirt on one side the ants might go to that side because of their preference for a quality of dirt other than its darkness. He then clarified why he did not want to include dirt at all:

Emilio: But we shouldn't put dirt on both sides 'cause then one side—both of the sides are still gonna be dark. One is just gonna be darker.

He then went on to elaborate:

Emilio: *No* sides with the dirt 'cause if you put dirt in both sides and cover one here [moves hand over left side] this one's gonna be darker but this one's [moves hand to right side] still gonna be dark.

Here Emilio spoke from within different imagined worlds, at the same time evaluating each with respect to an argument about ants' preference for darkness. He worked initially with Yolanda's idea to include dirt on both sides. He knew, based on his earlier analysis, that he could not put dirt on one side, but seemed to be wondering here whether it was possible to put it on both sides. As he took on Yolanda's idea, he spoke hypothetically, imagining dirt on both sides: "If we put dirt we should put dirt on both sides..." This hypothetical possibility seems conditioned by his earlier analysis of the problem of including dirt on the dark side; he seems to be saying implicitly that including dirt on both sides would control for its otherwise confounding effect. However, as he knows from his earlier analysis, the inclusion of dirt, whether in one or both sides, does not take care of the problem of restricting darkness to one half of the box. Seeing this, he quickly shifted to an alternative space, one that has the force of an imperative: "we *should not* put dirt [and] on no sides..." He moved out of the hypothetical space of Yolanda's design—he literally caught himself in this space mid utterance and reoriented himself away from it—and then negated it entirely: "If we put dirt we should put dirt on both sides" becomes "We should not put dirt [and] on no sides." He now inhabited a space that was dirtless. The intensity of Emilio's feeling here for the correctness of his thinking shows throughout this exchange, and especially in the utterances which follow. In these, he insistently elaborated his thinking by making explicit the problem of including dirt on both sides: "This one's gonna be darker, but this one's still gonna be dark."

Thus, at this juncture, the boundaries between inside and outside perspectives seem blurred. In Emilio's talk, imagined spaces and arguments about knowledge claims seem indistinguishable. His insistent, emphatic use of language ("We should not put dirt..."; "*no* sides with dirt"), in contrast to his earlier more hedged, tentative approach, testify to the cumulative force of his analysis. He has developed a feel for the ant world from the inside, what ants might experience in relation to the various components of the worlds being designed as well as a feel for his needs as a claimant in relation to these worlds and to the question at hand. Thus, when he says that both sides will still be dark but one will be darker if they put dirt on both sides, he is at once imagining these worlds in relation to ants' experience of them and evaluating them in relation to the complication they pose for the question being investigated.

We do not have the space here to continue the analysis. However, we want to note that as Emilio and his fellow students continued to work on this problem, they came to worry about other features of their designs: in particular, the water tube in Emilio's. Juan helped Emilio see the water tubes as embodying, like dirt, various dimensions other than darkness: water, cotton, and a place to hide from potential threats. As Juan noted at one point during the discussion of the tubes, "We're trying to see one thing and it's coming out other things. Instead of ... seeing if they like the dark, we see they like the cotton." Together they worked out a new way to provide ants with moisture. They decided to eliminate the tubes altogether, using instead a bottle cap with water which Emilio placed in both sides of the container. His final design is shown in Figure 1, Design 4.

Rethinking Experimentation. The kind of imagining analyzed here—of inhabiting a created world to explore what might happen or how something might react—has been documented in the everyday work of scientists in both physics and life sciences (Fox-Keller, 1983; Ochs et al., 1996; Root-Bernstein, 1989; Salk, 1983; Wolpert & Richards, 1997). Ochs et al. (1996) showed how physicists in a solid-state physics research group took on the perspective of the objects they were analyzing. As they worked to interpret a graph of state transitions, for example, they involved themselves in graphic reenactments of the physical events experienced by the focal object: "But as you go below the first order transition you're still in the domain structure 'n you're trying to get out of it." Or, "When I come down I'm in the domain state." Ochs et al. made the point that these sorts of blended identities—the "I" that is at once the animate physicist and the inanimate physical entity—allow the scientists to "symbolically participate in events from the perspective of the entities in worlds no physicist could otherwise experience" (p. 348). This kind of imaginative participation in the represented world of physical events is thus a resource to physicists' thinking, particularly as they work through unresolved problems or explore implications of a model.

The interplay of what we have called inside and outside, or imaginative and evaluative, perspectives formed the ground of Emilio's experimental reasoning. It entailed on the one hand his taking up a point of view within the world he was creating, imaginatively inhabiting it to envision events and outcomes, and on the other evaluating the imagined events from outside of this world in light of possible knowledge claims. These two perspectives were fully intertwined in Emilio's work. By imagining how ants might experience dirt he was able in some sense to give them reason; these reasons had consequences for the kinds of evidence on which he would be able to draw in making and supporting his claims. Likewise, his emerging needs as a claimant gave shape to the possible meanings of elements (or variables) in the world he was designing.

We propose that Emilio was engaged not in the logical task of identifying variables, but in the messy task of constructing variables—that is, of having to construct relevant distinctions between sources and kinds of darkness in the particular world of ants he was designing for a particular purpose. We use the term *constructing* in both conceptual and material senses, which in Emilio's work as in much experimental handiwork are nearly impossible to separate (Gooding, 1992; Lynch, 1985; Rheinberger, 1987; Root-Bernstein, 1989). As Emilio worked to create an experiment that could provide suitable evidence about ants' preference for light or darkness—an experiment which would operationally confine darkness to one of the two halves of the imagined box—he in effect confronted the question, "What will count as darkness in the world of this experiment?" His answer, and the meaning of darkness, shifted as he explored each successive design from both an ant's and a claimant's point of view, e.g., darkness as a wrapped tube, darkness as a top cover, darkness as a quality of dirt. In other words, each of his moves within the emergent world of the experiment and each of his moves to evaluate that world conditioned potential meanings of darkness and possible knowledge claims. In the last utterance we cite ("*No* sides with the dirt"), Emilio was emphatic in wanting to create an unambiguously dark side or condition. At the same time the significance of specific material elements shifted as well. Dirt was not the same object for Emilio by the end of the episode as it was when he initially introduced it.

How do we see Emilio's work in relation to accounts of children's scientific reasoning in the science education literature? We do not see Emilio as applying a form of logical reasoning to identify the variable darkness, although the result of his concerted work was a logically sound and scientifically rigorous analysis. Rather, we see that for Emilio ordinary things such as dirt and darkness, which in everyday usage pose little problem of meaning, came to require extraordinary work of specification, connection, and contrast. He constructed an increasingly more specified meaning of darkness by exploring the various ways in which it might be related to material features of the designed world of the experiment, the physical life of ants, and a discursive world of possible knowledge claims. Through his work, Emilio created a stable, experimentally sound meaning for darkness out of various potential meanings, which he achieved in interaction with the lived-in environment of the experimental world he was creating; in short, he had to select and develop aspects of darkness in relation to both assumed and emergent material, symbolic and discursive elements finally to isolate it from dirt.

It may be that we see Emilio's work as expanding on traditional conceptions of scientific reasoning in part because his task involves designing a world rather than selecting and testing already configured variables, as in traditional studies. In our task, darkness is not given but must be constructed, with one result being that certain practices which are lost in traditional predesigned tasks perhaps become more visible. We learn from Emilio that the significance of darkness does not inhere in the word or in a single concept but in its relation to the material, symbolic, and discursive situations of its use: darkness in the world of this experiment is not the same as the darkness of the night to a frightened child. Nor, as Emilio discovered, is the darkness of dirt the same as the darkness of a wrapped water tube. In contrast to the world of traditional studies in which children reason in a world of predefined relationships and outcomes, here Emilio and others in his class were able to use the inherent polysemy of any given variable, alone and in relation to others, as a resource rather than hindrance in their thinking about confoundedness. They did so by inhabiting the experiment as a world made up of shifting relations among material things, imagined experience, and knowledge claims. Emilio, we would argue, learned something deep about what it means to experiment:

> It is only in the process of making one's way through a complex experimental landscape that scientifically meaningful simple things get delineated; in a non-Cartesian epistemology, they are not given from the beginning. (Rheinberger, 1997, p. 28)

Conclusion

In this article we have argued for and illustrated our efforts to understand children's diverse sense-making practices as an intellectual resource in science learning and teaching. We have argued for the importance of taking seriously the ideas and ways of talking and knowing that children from diverse communities bring to science. In our view, too little attention has been paid by researchers and teachers alike to the potentially profound continuities between everyday and scientific ways of knowing and talking, and thus to the pedagogical possibilities that may be derived from such an analysis, especially for typically marginalized children.

By continuities, we have in mind something at once more complex and more challenging than similarity or difference, as we hope the previous two analyses suggest. We are arguing for the need to analyze carefully on one hand the ways of talking and knowing that comprise everyday life within linguistic, racial, and ethnic minority communities, and on the other, the ways of talking and knowing characteristic of scientific disciplines (recognizing that even here there are important differences, say, between modes of explanation in physics and evolutionary biology). This analysis assumes that what children from low-income, linguistic, racial, and ethnic minority communities do as they make sense of the world—although perhaps different in some respects from what European American children are socialized to do—is in fact intellectually rigorous and generatively connected with academic disciplinary knowledge and practice (cf. Lee, 1998).

In science education research, researchers' and teachers' evaluations of children's talk as scientific or not derive in significant part from their view of what constitutes scientific practice and ways of knowing. Often, the ways of talking, making arguments, and developing theories which are thought to constitute science are seen as distinct from the linguistic and social practices used in everyday life, especially those used in certain minority communities (Lee & Fradd, 1996, 1998). Students such as Jean-Charles and Emilio, who speak in less formal ways, who imagine themselves into the phenomena they are trying to explain, or who play with the affordances of different languages to develop contrasts among seemingly unambiguous ideas such as growth and darkness may be heard in many classrooms as something less than scientific. One result is that space is not provided in the classroom for the kind of intellectual work that these students are doing. Another is that their contributions may not be taken up by the teacher, except perhaps to correct them, or by other students (Gee & Clinton, in press; Michaels, 1981; Michaels & Bruce, 1988; Michaels & Sohmer, 2000; Pothier, 1999; Rosebery & Warren, 1999). In both cases, their sense of themselves as learners and thinkers may consequently be diminished. Thus, a narrow view of what constitutes scientific ways of knowing can lead to a narrow range of responses to some children's ideas, which in turn can lead to limited participation by these children in science. Likewise, a limited view of the meaning-making afforded by some children's everyday language—in both senses as we discussed in the case of Jean-Charles—can lead to misevaluations of the depth and complexity of their sense-making in science. We suggest that the misunderstandings that emerge from sequences of situated responses and actions between teachers or researchers and students can help explain why the sense-making resources of children from diverse communities are so rarely seen and valued in the science classroom.

What can be gained from reconceptualizing children's diverse sense-making and scientific sense-making as potentially complementary rather than discontinuous? We have learned from our research to question taken for granted, standard formulations of the differences between scientific language and practices and those human beings variously use in their everyday lives. Emilio and his classmates, for example, opened up for us perspectives on experimentation we had not previously considered, which continue to resonate in our thinking and research. As we observed how these children approached the problem of designing an experiment in ways that seemed outside the canonical approach—imagining themselves into the ants' world, evaluating claims, constructing rather than identifying variables—we had to confront our own assumptions about the nature of experimental thinking as exclusively a mode of logical inference. As we examined Emilio's work, we were struck by how his practice of imaginatively inhabiting the experimental world—what at another time we might have seen as anthropomorphism—was actually a generative practice for exploring the created world of the experiment to evaluate relevant knowledge claims. This process led Emilio to see in what ways specific material elements (i.e., variables and conditions) of the experimental world were confounded and how to design the world in a way which looked in the end fully canonical.

Likewise, from Jean-Charles we are able to document just how flexible languages are as well as the kinds of affordances languages with histories as different as HC and English may offer to a child who is learning science. The potential of a child's language, in both senses, as a generative tool in making scientific meaning is always there, provided the situation in which it is being used supports its significance. What Jean-Charles was able to accomplish was in no small part due to the classroom community established by his teachers, which explicitly enlisted and built on the children's everyday modes of argumentation, questions, and perspectives in interaction with the teachers' own scientific questions, perspectives and understandings. The same holds in the case of Emilio, whose ability to respond to the challenges posed by the interviewer and his peers was anchored at least in part in his participation in the discourse norms and practices of his classroom, where incidentally he was not a particularly vocal participant.

We suggest that as educators we need to take seriously the intellectual power and complexity in the ways with words children, and all of us, use every day. We have met educators, both teachers and researchers, who believe they are being compassionate when they say that children whose parents do not speak English, were not able to be educated formally themselves, or work too hard to talk to their children about their homework or read storybooks to them cannot do the same things in school that children with college educated parents can. They often say that they realize these children are intelligent but they have not had the same advantages as other students. They wonder how they can expect as much from them. We suggest that when they say this sort of thing they are assuming that the way these children speak in their homes—their everyday language in both senses—does not contain the same capacity for deep thought, refinement of ideas, or complex argument that they believe is inherent in the language of children of educated parents. They see linguistic, racial, ethnic minority and low-income children as cut off from important forms of expression and thought, from cultural traditions that middle-class English-speaking children gain by means of their language and socialization. Our work and that of others (Foster, 1999; Gee, 1990; Heath, 1983; Hymes, 1996; Labov, 1972; Lee, 1993, 1998; Smitherman, 1977) shows that children, regardless of their national language or dialect, use their everyday language routinely and creatively to negotiate the complex dilemmas of their lives and the larger world. Likewise, in the science classroom children's questions and their familiar ways of discussing them do not lack complexity, generativity, or precision; rather, they constitute invaluable intellectual resources which can support children as they think about and learn to explain the world around them scientifically.

We think it is crucial that the diverse ideas and ways of talking and knowing of all children be brought into contact with each other as well as with standardly recognized views and modes of organizing explanations and arguments (Ballenger, 1997; Rosebery & Warren, 1998b; Warren & Rosebery, 1996; Warren et al., 1999, 2000). By this, we do not mean to imply a picture of science learning as simply the accumulation of different ways with words and ways of seeing. Rather, we see contact among different perspectives as a creative critical process (Bakhtin, 1981) in which diverse ways with words and ways of seeing are probed, challenged, and perhaps even transformed to the benefit of all students.

Like others in this field, our goal is for all children, but particularly those currently being left behind, to be able to demonstrate robust understanding and achievement across a repertoire of performances and assessments of disciplinary knowledge and practice. Traditionally, those who have thought about the relationship between particular cultural groups and the culture of science have identified tensions between what they describe as the knowledge, values, and practices of science and the knowledge, values, and practices of children from particular racial, ethnic, and linguistic minority communities. We would argue that the perspective we have put forward in this article can effectively reframe these tensions by opening up for examination what is meant by science on the one hand and diversity in cultural and linguistic practices on the other. By examining both in an integrated and reflexive way, we can begin to envision pedagogical possibilities that build on diversity as an intellectual resource rather than a problem or tension in science learning.

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Notes

[1]For further discussion of this case, see Ballenger (2000).

[2]This science circle took place in Haitian Creole; it has been translated into English for the purposes of this article.

[3]Parentheses indicate a hard to hear utterance and our guess as to what the speaker said. Words or phrases in parentheses separated by a "/" indicate two possible hearings.

[4]Our research corpus includes many instances of both students and teachers engaging in this practice as they grapple with their understanding of complex phenomena (Rosebery, 2000; Warren et al., 2000).

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