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ABSTRACT

This paper discusses teaching science to language minority students and describes work with linguistic minority children and their teachers. A key goal of this work is to create scientific sense-making communities in the classroom that parallel science as it is practiced in the world. Following a critique of current practice in science education, the paper explores what conditions are necessary to create classroom communities of scientific sense-making. This is followed by a look at a new approach to teacher development based on the belief that the teacher, whether bilingual, English-As-A-Second-Language, or science specialist, is critical to creating communities of scientific sense-making. Also discussed is the role of discourse appropriation in teacher development, with an example of teachers and students reviewing a homework assignment on acids and bases. A case study of one teacher's experience of learning science in order to teach science illustrates the nature and complexity of the learning process that undergirds the creation of classroom communities. A conclusion brings the issues together and emphasizes that in their reflective practice, teachers can construct a view of science as a socially constituted, meaning-making activity that includes rather than excludes linguistic minority children. (Contains 62 references.) (JB)

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Contents

Preface

TERC is a nonprofit education research and development organization founded in 1965 and committed to improving science and mathematics learning and teaching. Our work includes research from both cognitive and sociocultural perspectives, creation of curriculum, technology innovation, and teacher development. Through our research we strive to deepen knowledge of how students and teachers construct their understanding of science and mathematics.

Much of the thinking and questioning that informs TERC research is eventually integrated in the curricula and technologies we create and in the development work we engage in collaboratively with teachers. In 1992 we launched the TERC Working Papers series to expand our reach to the community of researchers and educators engaged in similar endeavors. The TERC Working Papers series consists of completed research, both published and unpublished, and work-in-progress in the learning and teaching of science and mathematics.

Introduction

Equity in science for linguistic minority children can have at least two meanings. Cast in the present tense, calls for equity mean providing linguistic minority children with the *same* educational opportunities currently available to children in the educational mainstream: the same science, the same mathematics, and so forth. Cast in the near future tense, calls for equity express a critique of current mainstream practice. What is needed, these critiques say, is not more of the same, nor even a more efficient version of current practice, but an entirely different kind of science and mathematics practice. This point of view is tied to the science and mathematics education reform movements, although more implicitly than explicitly, because the documents representing these movements (AAAS, 1989; NCTM, 1989; NRC, 1989) unfortunately do not deal assertively or deeply with issues of equity for linguistic minority children (Meyer, 1989).

Secada (1989; W. Secada, personal communication, August 4, 1992) uncovers part of the dilemma embodied in these two meanings of equity by analogy to a "moving target." He argues that if we take current practice as the object of equal opportunity, then we are committing to the view that current practice in science and mathematics is worthy of emulation. In his opinion, it is not. Therefore, equity must be conceptualized in the future tense, with science and mathematics envisioned as something other than the textbook and demonstration-based curricula they currently are.

We believe the dilemma runs even deeper. If we target the near future and involve linguistic minority children in different, "progressive" forms of scientific and mathematical practice, the children are still accountable — at least for the present — to the terms set by current practice (e.g., standardized tests). Delpit (1986, 1988) frames the argument as follows. Progressive pedagogies, which she defines as emphasizing meaning over form, process over product, contextualized learning over decontextualized learning, may actually undercut minority children (she is speaking specifically of African-American children). African-American children, she argues, have meaning and fluency; what they need to develop are the skills — control over specific written and spoken discourse forms—that middle class children learn at home and get to practice at school. Delpit advocates a more reasoned interaction of skills and process, meaning and form, one that would allow for the representation of "multicultural voices" in determining the shape of progressive educational practice. She also argues for the explicit teaching of the "culture of power" (e.g., ways of talking, writing, interacting, valuing) to children outside that culture (e.g., poor, non-white, non-English speaking children). Without such explicit teaching, she maintains, minority children will not acquire the discourse patterns, interactional styles, and spoken and written language codes they need to succeed in the larger society.

We believe, in accord with Secada's (1989) position, that equality of educational opportunity in science cannot be achieved by importing mainstream school science into linguistic minority classrooms. However, in defining a new kind of science practice, we also seek to respond to the dilemma articulated by Delpit. We believe, as we think Delpit (1986, 1988) does, that we can redefine science in schools so that it admits diverse sense-making practices, carries with it more egalitarian values, and ensures that linguistic minority students acquire the mainstream literacies they need to succeed in school and beyond (Rosebery, Warren & Conant, 1992; Warren, Rosebery & Conant, in press). Our view is that mainstream literacies, rather than defining how science is practiced in schools, must be embedded in an entirely different kind of practice.

In this paper we describe our work with linguistic minority children and their teachers, one goal of which is to create scientific sense-making communities in the classroom that parallel in some important respects science as it is practiced in the world. In particular, we explore the question "What conditions are necessary to create classroom communities of scientific sense-making?" by focusing on our work with teachers of linguistic minority children. We believe that the teacher, whether bilingual, English-As-A-Second Language (ESL), or science specialist, is critical to creating such communities. Through a case study of one teacher's experience of learning science in order to teach science, we aim to illustrate the nature and complexity of the learning process that undergirds the creation of classroom communities of scientific sense-making. To set the context for the case study, we explore current classroom practice in science, outline what we mean by a sense-making perspective, provide examples of students' scientific activity, and summarize what students learn in a sense-making culture.

A Critique of Current Practice in Science Education

Why is current practice in science, which emphasizes textbook and demonstration-based learning, a bad model? Quite simply, because it does not work. Numerous reports testify to the sorry state of science education (Mullis & Jenkins, 1988). One recent publication reports that three-fourths of American high school graduates do not take science after the tenth grade (NSTA, 1992). Except for a narrow elite, most students are put off by science with its emphasis on assimilating textbook knowledge, answering known information questions, and making abstract connections in decontextualized situations.

This estrangement from science is exacerbated in the case of minority students. In general, they have less access to science, owing to stratification processes and resource limitations (Kozol, 1991; Mehan, 1991; Oakes, 1985, 1986). But access alone does not guarantee equal opportunity. As numerous studies have shown, the ways of knowing, talking, interacting, and valuing of low-income, African-American, and linguistic minority communities differ from those enacted in the mainstream science classroom (Au, 1980; Erickson & Mohatt, 1982; Heath, 1983; Michaels, 1981; Michaels & Bruce, 1989; Philips, 1972; Scollon & Scollon, 1981). School science as currently constituted privileges mainstream, middle class ways of knowing (even if it does not succeed in engaging the interest of most middle class children).

Furthermore, as Gee (1990) argues, schools may be good places to *practice* mainstream ways of talking and knowing but they are not good places to *acquire* them. In current science classrooms, this problem is particularly acute because students do not often get to use scientific language themselves to construct meaning. In his study of the forms and functions of classroom science talk, Lemke (1990) reports that the predominant form of classroom science talk conforms to the pattern of Teacher Question-Student Answer-Teacher Evaluation (Triadic Dialogue). Forms of talk involving authentic conversation (True Dialogue and Cross-Discussion in Lemke's terms) are rarely found, except when the subject is not science but some non-academic topic such as classroom business. Moreover, even when students do get to use language to construct scientific meaning, their sense-making may not always be understood if they talk science in nonstandard ways (Lemke, 1990; Michaels & Bruce, 1989). As Michaels and O'Connor (1990) suggest, teachers may privilege those students whose ways of talking are the same as theirs. One result is that students who talk science in nonstandard ways may be judged "not smart enough" to study science, let alone become scientists.

As Lemke (1990) argues, two sets of beliefs about science undergird mainstream practices and judgments about who can and cannot do science. One has to do with the "ideology of the *objective truth* of science" (p. 137), namely, that science is about facts that are indisputable and authoritative, based on observation and experiment and independent of theory. Science appears as something other than the human, meaning making, and socially constructed activity it is (Knorr-Cetina & Mulkay, 1983; Latour & Woolgar, 1986). The other set of beliefs Lemke calls the "ideology of the *special truth* of science" (p.138), by which he means that in schools students learn that science is a truth accessible only to experts, utterly opposed to common sense. According to this view, scientific knowledge is not only fixed and authoritative, but is constituted by extraordinarily gifted individuals. Science, so the ideology goes, is such a difficult subject that only the specially talented can ever hope to master it. Those who cannot just aren't smart enough and either opt out of science or are excluded by stratification processes (Mehan, 1991; Oakes, 1985, 1986). Lemke (1990) elaborates this argument in the following:

> No one points out that science is taught only in very restricted ways. The restrictions tend to insure that only people whose backgrounds have led them to already talk a bit more like science books do, to already learn in a particular style and at a particular pace, to already have an interest in a certain way of looking at the world and certain topics and problems, will have much chance of doing well at science.

> It is not surprising that those who succeed in science tend to be like those who define the "appropriate" way to talk science: male rather than female, white rather than black, middle- and upper-middle class, native English speakers, standard dialect speakers, committed to the values of North European middle-class culture (emotional control, orderliness, rationalism, achievement, punctuality, social hierarchy, etc.). No one points out that science has been done very effectively by other sorts of people in other kinds of cultures, or that science might look a little different in its models and emphases if its recent history had come at a time when other cultures had been politically dominant in the world and in a position to command more of its resources (say Italy, or China, or India). (p. 138)

Not only is current school science bad science practice, it also marginalizes those students who do not already control mainstream ways of knowing and talking. As we noted above, it also appears that, except for a narrow elite, many middle class students are put off by school science. In the face of this reality, the equity question then becomes one of how to make science into an activity in which all students can participate successfully. But this perspective has its dangers, too. In fact, most, if not all, of the major reform documents in science and mathematics state their commitment to the education of all students (AAAS, 1989; NCTM, 1989; NRC, 1989). But they are consistently vague on how minority students are to be brought into the reform movement. How exactly will they participate? To what extent will reforms take into account their culturally based practices and specific educational needs?

Typically, the details of reform are worked out in mainstream contexts, with the implication that they can then simply be imported into non-mainstream contexts (e.g., bilingual education). But, in fact, reforms rarely "trickle down" (Secada, 1989), in part, because they have not been explicitly conceptualized in terms of non-mainstream contexts and concerns and are therefore inappropriate. Other factors also impede reform in non-mainstream contexts. Cole and Griffin (1987) specifically point to the economic and political pressures on schools serving mostly minority populations to reduce dropout rates and improve achievement test scores:

> . . . [I]t is not surprising that educators of minority students are pressured to "do the basics" better and leave innovative educational practices to others. However, a continued imbalance in the educational mandates that guide the education of minorities and of white middle-class children deepens the problem: as schools serving minority children focus their resources on increasing the use of well-known methods for drilling the basics, they decrease the opportunities for those children to participate in the higher level activities that are needed to excel in mathematics and science. (pp. 4-5)

We have framed our work in light of these concerns. In seeking to define a new kind of scientific practice in the classroom, we have deliberately located our effort in linguistic minority contexts.

A Sense-Making Perspective on Science

For the past four years in the Cheche Konnen project ("search for knowledge" in Haitian Creole) we have been collaborating with classroom bilingual, ESL, and science teachers from the Cambridge and Boston, Massachusetts, public schools to understand science as a sense-making activity. Together we have been exploring how to create communities of scientific practice in language minority classrooms (Rosebery et al., 1992; Warren et al., in press), that is, classroom communities that parallel in some important ways science as it is practiced in the professional world. Our goal is to make school science more into a way of working and meaning-making than a static set of concepts acquired in the context of an abstracted and generic methodology.

In our research, we are exploring what, if any, might be the connection between scientific practice in professional scientific communities and in schools. We assume, first and foremost, that scientific practice in the world is heterogeneous rather than unitary (Latour & Woolgar, 1986; Lynch, 1985). In actual scientific practice, competent practitioners orchestrate a variety of mediational means (e.g., tools, discourses, genres) to construct scientific meaning. Secondly, we assume that scientific practice in schools may not, and even should not, look exactly like scientific practice in the world. Nevertheless, we believe that there is much to be learned about what science in schools can be by examining science as it is practiced in professional communities. Understanding the relationships between these communities will help us ultimately to clarify what it means to "learn science."

What, then, is the nature of scientific practice? In trying to understand this, we have examined several sources: in particular, writings from the sociology and ethnography of scientific work and writings of scientists themselves (Feynman, 1988; Knorr-Cetina & Mulkay, 1983; Latour, 1987; Latour & Woolgar, 1986; Longino, 1990; Lynch, 1985; Medawar, 1987). A central theme has emerged from our reading of this literature: scientific practice is a *socially and culturally mediated process of meaning construction and criticism.*

For example, the Nobel Laureate scientist, Sir Peter Medawar (1987), compellingly describes scientific practice as a particular kind of storytelling:

> Like other exploratory processes, [the scientific method] can be resolved into a dialogue between fact and fancy, the actual and the possible; between what could be true and what is in fact the case. The purpose of scientific enquiry is not to compile an inventory of factual information, nor to build up a totalitarian world picture of Natural Laws in which every event that is not compulsory is forbidden. We should think of it rather as a logically articulated structure of justifiable beliefs about a Possible World – a story which we invent and criticize and modify as we go along, so that it ends by being, as nearly as we can make it, a story about real life. (p.111)

Medawar's use of the story metaphor represents a bold challenge to both typical school beliefs about what it means to be scientifically literate and the larger culture's assumptions about the nature of scientific knowledge and work. First, he directly challenges the belief that science is, at bottom, the accumulation of factual information about the natural world. Second, he challenges the belief that scientists work according to a rigorously defined, logical method, known popularly as the scientific method. And third, through his emphasis on storytelling (by which he means theory building and criticism), he challenges the belief that scientific discourse—the construction of scientific meaning—is represented uniquely by forms of writing and talk that are thoroughly objective and impersonal.

Central to Medawar's vision is an idea of scientific practice in which creativity, construction and criticism—rather than discovery—predominate. His language suggests that science is projective rather than objective: scientists build stories about a Possible World, they do not discover the truth that already exists just waiting to be uncovered. Further, he insists on the dialogic quality of scientific activity: fact and fancy, invention and criticism interacting.

Contemporary sociological and ethnographic studies of the nature of scientific activity in laboratory settings add an explicit social dimension to this picture (Knorr-Cetina & Mulkay, 1983; Latour, 1987; Latour & Woolgar, 1986; Longino, 1990; Lynch, 1985). These studies show that scientists construct and refine their ideas within a community in which they transform their observations into findings through argumentation and persuasion, not simply through measurement and discovery. The apparent "logic" of scientific papers—the very thing that gets modeled in many science texts as the Scientific Method—is really the end result of the practice of a group of scientists who, through informal and formal talk, graphs, notes, statements, drafts of papers, and published papers, construct accounts ("stories"), negotiate claims, and put forward and defend arguments, and the like (Latour & Woolgar, 1986). Interestingly, when asked what they are doing, the scientists claim merely to be discovering facts; but close observation reveals that they are actually writers and readers in the business of being convinced and convincing others. (It is hard not to hear an echo of Medawar's storytelling in this.)

How is this view of science realized in the classroom? In Cheche Konnen, science is organized around students' own questions and inquiries. Students design studies to explore their questions; collect, analyze and interpret data; build and argue theories; establish criteria and evaluate evidence; challenge assumptions; draw conclusions; and, where appropriate, take actions based on their results. Much of the science that goes on (the "curriculum") emerges from the students' own activity, the questions they pose, the dilemmas they meet, the observations they make, the experiments they design, the theories they articulate.

Over the past four years, students' scientific activity has encompassed different phenomena and taken various forms. Students from kindergarten through high school have investigated the ecology of a local pond, the acoustics of a traditional

Haitian drum, their local weather, and the relationship between salt intake and physical fitness. In addition to ranging in age, the students are linguistically and culturally diverse (representing seven countries), and vary in educational experience. Most students are judged to be two or more years below grade level. Some cannot read or write even their first language. Some have never been to school before.

What does an investigation look like? One class of seventh and eighth grade Haitian students conducted a study that came to be known as "The Water Taste Test." The students investigated a belief widely held in their class and the other junior high classes in their school that the water from the school's third floor fountain (where the junior high is located) was better than the water from the other floors. Using a series of blind taste tests, they determined that their belief was not supported by the data. Most of the junior high actually preferred the water from the first floor fountain, a result which horrified them because "all the little kids slobber in it." This result, however, raised a new question: What was the source of the first floor preference? They analyzed several possible causes and concluded that temperature was a deciding factor. The first floor water was 20 degrees colder than that on the other floors. They also uncovered high bacteria levels for all the school fountains, which led them to contact the local water department (see Rosebery et al., 1992, for further details).

At the same school, three kindergartens—one bilingual and two monolingual (English speaking)—have collaborated in science for the past three years. In the first year they studied their local weather, in the second sound, and in the third trees. During their investigation of sound, the work in one of the monolingual kindergartens took an interesting turn when the children and their teacher decided to soundproof their bathroom. They were driven to this because the noise of the flush, which was magnified as it reverberated off the bare tile walls, so frightened some of the children that they refused to go to the bathroom. Using boxes of increasingly larger size (from standard shoeboxes to wardrobe moving boxes) and alarm clocks, the students explored the sound dampening properties of a variety of materials (cotton balls, sheet rock, tissues, styrofoam, bubblepack, egg cartons). To determine the relative "soundproofness" of these materials, they learned to read and interpret a decibel meter. Based on the results of their experiments, the children chose to cover the walls of their bathroom with foam rubber. This reduced the noise level from 89 to 76 decibels. (A jack hammer is approximately 95 dB; normal conversation is approximately 65 dB.)

These investigations had several characteristics in common with the work of scientists. They were generative and constructive in character: one question or problem led to others. In their work, the students explored the relationships among theory, observation, and evidence. And like scientists, they worked at constructing arguments and marshalling evidence to persuade others (students as well as teachers and other members of the school community) of their point of view.

In addition, through their investigations the students learned and practiced mainstream literacies: asking questions, taking notes, arguing different points of view, writing in various genres, and using mathematics in various ways to construct scientific meaning. For example, in the Water Taste Test, the students developed surveys, wrote reports, and publicly presented their findings. They also grappled with statistical issues of sample size, bias, and graphical representation. In the weather and sound studies, the kindergartners (both monolingual and bilingual students), learned to count to 100 by ones and tens, explore patterns in complex data, read and make graphs, and add and subtract as they became increasingly proficient with such measurement tools as thermometers, anemometers, and decibel meters. We believe that this kind of science represents an intellectually and linguistically richer enterprise than most current school science, one that conveys more clearly an image of what it means to do science and be scientific.

What do students learn when they participate in scientific sense-making communities of the kind described above? To answer this question, we interviewed students who participated in the Water Taste Test to find out how their scientific knowledge and thinking developed over the school year (see Rosebery et al., 1992, for full details). Students were asked to "think aloud" about how they would investigate and explain two realistic, open-ended problems. The problems were designed to explore students' use of hypotheses, experiments, and explanations to organize their scientific reasoning. One problem focused on pollution in the Boston Harbor and the other on a sudden illness in a school.

There were striking changes in the students' talk from the beginning of the school year (September) to the end of the year (June). Not surprisingly, students knew more about water pollution and aquatic ecosystems in June than in September. More importantly, however, they were able to use this knowledge generatively in thinking through real world problems. One student, for example, described in detail the processes of chlorination and flocculation when asked to explain how she would clean the water in the Boston Harbor.

During the year, the students' scientific thinking deepened. At the end of the year, the students were using conceptual systems to generate hypotheses and experiments (e.g., linking man-made waste disposal systems and groundwater contamination to water pollution). This contrasts with the start of the year when they either asserted information stated in the problem description or put forward black box conjectures having no explanatory power: "people," "stuff they put in," "a poison."

In addition, the students used hypotheses differently. In the spring, they used hypotheses to organize their scientific reasoning, going beyond the information stated in the problem to put forward testable conjectures. They treated the facts recounted in the problems as *symptoms* of an underlying problem in need of explanation rather than as the explanation itself as they had in the fall. They also used hypotheses to give direction to their inquiry and to connect stated symptoms to something smaller and more precise than the phenomena described in the problem.

In the spring interviews, hypotheses also functioned as part of a larger inquiry process linking conjecture and experimentation. The students no longer conceptualized evidence simply as information already known (i.e., through personal experience) or given; rather, they conceptualized evidence as the product of experimentation they would undertake to confirm or disconfirm a given hypothesis. This contrasts with their fall interviews in which they interpreted an elicitation for an experiment ("How would you be sure?" "How would you find out?") as a text comprehension question for which there was a "right" answer. In June, however, they showed that they were beginning to understand the function of and relationship between hypotheses and experiments. For example, they sketched experiments that were designed to test their hypotheses directly. When asked to explain the "logic" of their experiments, the students showed that they were thinking through the deductive consequences of their hypotheses and understanding critical aspects of experimental design (e.g., isolating a single variable).

One final note about what students learned as they carried out the Water Taste Test. From September to June, we noticed a subtle but important change in the voice the students used to respond to the interviewers' questions. In September, much of their discourse was enacted through the omniscient third person ("they put," "they left"), with occasional uses of the first person to tell stories from personal experience. In June, in contrast, a different voice emerged: the first person dominated but the "I" was distinctly different from the "I" occasionally heard in September. In June, the "I" was functioning authoritatively as the voice of an active problem solver.

Defining a New Approach to Teacher Development

The teacher plays a pivotal role in orchestrating scientific sense-making. Actually, the teacher takes on several roles: co-investigator, mentor, facilitator, group leader, at times master practitioner, even occasionally lab assistant. This view of teaching is markedly different from the one enacted in conventional school science.

How do teachers learn to take on these new roles in the classroom? How do they learn to shape and support students' sense-making? We believe it is by appropriating the values and ways of knowing that are associated with scientific practice and linking these through reflection to teaching and learning (Schön, 1987).

Socially shared cognition and *situated learning* are two terms used in the research literature to describe a new conceptualization of learning (Brown & Campione, in press; Brown, Collins & Duguid, 1989; Lampert, 1990; Resnick, Levine & Teasley 1991; Schoenfeld, 1992, in press). Integrating perspectives on learning and cognition from Soviet psychology (Vygotsky, 1978, 1985), cognitive science (Collins, Brown & Newman, 1989) and anthropology (Geertz, 1973, 1983; Lave, 1991; Lave & Wenger, 1991; Rogoff, 1990), this new view frames learning as an inherently cognitive *and* sociocultural activity. The learner, whether student or teacher, appropriates new forms of discourse, knowledge, and reasoning through his or her participation in socially defined systems of activity or *communities of practice* (Lave, 1991). As Resnick (1989) has recently argued, education may be better thought of as a process of socialization, rather than instruction, into ways of thinking, knowing, valuing, and acting that are characteristic of particular disciplines.

Central to this sociocultural view is the idea that concepts are constructed and understood in the context of a community or culture of practice; their meaning is socially constituted (Brown et al., 1989). Within this community, moreover, practitioners are bound by complex, socially constructed webs of belief which help to define and give meaning to what they do (Geertz, 1983). As Mehan (in press) has noted, members of a community "can not make up meanings in any old way." Rather, they build up ways of knowing, talking, acting, and valuing—particular ways of interpreting questions, giving explanations, telling stories or developing evidence—which organize meaning making within the community. Within this sociocultural framework, the learner is conceptualized as one who *appropriates* new forms of knowledge through apprenticeship in a community of practice (Brown & Campione, in press; Brown et al., 1989; Collins, Brown & Newman, 1989; Lampert, 1990; Lave, 1991; Resnick, 1989; Rosebery et al., 1992; Schoenfeld, 1992, in press; Warren et al., in press).

From this perspective, learning in school really means *appropriating whole systems of meaning* involved in such tasks as reading and answering questions about stories, talking to the teacher, taking tests, playing with other students in the schoolyard, doing mathematics, doing science, doing history (Gee, 1990; Michaels & O'Connor, 1990). From the perspective of the teacher, learning means appropriating new ways of thinking about science on the one hand and about teaching and learning on the other: for example, the intellectual value of asking and pursuing a scientific question, arguing one's point of view by marshalling evidence, making sense of another's point of view in relation to one's own. The notion of appropriation is critical because it casts the learner —whether teacher or student—as someone who is trying to find ways to take the sense-making practices of science and make them his or her own, tune them to his or her own intention, his or her own sense-making purposes.

But appropriating a new discourse is a difficult process, as Bakhtin (1981) explains:

> (The word in language) becomes "one's own" only when the speaker populates it with his own intention, his own accent, when he appropriates the word, adapting it to his own semantic and expressive intention. Prior to this moment of appropriation, the word . . . exists in other people's mouths, in other people's contexts, serving other people's intentions: it is

> from there that one must take the word, and make it one's own. And not all words for just anyone submit equally easily to this appropriation, to this seizure and transformation into private property: many words stubbornly resist, others remain alien, sound foreign in the mouth of the one who appropriated them and who now speaks them; they cannot be assimilated into his context and fall out of it; it is as if they put themselves in quotation marks against the will of the speaker. Language is not a neutral medium that passes freely and easily into the private property of the speaker's intentions; it is populated – overpopulated – with the intentions of others. Expropriating it, forcing it to submit to one's own intentions and accents, is a difficult and complicated process. (pp. 293-294)

What makes appropriation so difficult is that discourses are inherently ideological; they crucially involve a set of values and viewpoints in terms of which one speaks, acts, and thinks (Bakhtin, 1981; Gee, 1990). As a result, discourses are always in conflict with one another in their underlying assumptions and values, their ways of making sense, their viewpoints, the objects and concepts with which they are concerned. Each gives a different shape to experience. Therefore, appropriating any one discourse will be more or less difficult depending on the various other discourses in which students and teachers participate.

Through Bakhtin we can frame the challenge of teacher development as follows: how to enculturate teachers into scientific sense-making practices and values so that they can appropriate them to their own intentions. The idea is not simply to inculcate a new set of teaching strategies or implement new curricula, as is so often done in the name of teacher development and instructional reform, but to involve teachers in doing science and thinking about science as a discourse with particular sense-making practices, values, beliefs, concepts and objects, ways of interacting, talking, reading and writing. This "insider's view" of scientific practice can then form the basis for rethinking classroom practice.

The Role of Discourse Appropriation in Teacher Development

We have come to appreciate the importance of discourse appropriation as the basis of teacher education in part because of our own efforts early on in the Cheche Konnen project. At that time we did not understand, either in theoretical or practical terms, that what is at stake for teachers is their *identity* (Lave, 1991; Scollon & Scollon, 1981): the mostly tacit beliefs and values on which their pedagogical practice rests. As a result, we enacted a "model" of teacher development that focused on curriculum and instructional strategy.

During the summer preceding the first academic year of the project, a group of four teachers participated in a summer workshop held over several days. We walked the participants through a set of activities on water quality — essentially, an introductory curriculum—that they could take back to the classroom and do with their classes. The lessons were prescribed; they "led" the teachers through the "inquiry" process. (Note that this is a common model of teacher inservice education, one that is usually considered progressive.) We did not create a community in which the teachers were practitioners who did the work of scientific sense-making. One consequence of this approach was that the teachers did not have the opportunity to appropriate the values and practices of a scientific sense-making culture. They had no reason to uncover, let alone work through, any conflicts between their own viewpoints and values regarding proper instruction for language minority students and those underlying a sense-making perspective in science.

The transcript below illustrates the problems we encountered with this approach to teacher education. It is taken from research we carried out in a multicultural and multilinguistic high school class (Warren, Rosebery & Conant, 1989), which was part of a Basic Skills program within the school's bilingual program. It included those students who were not considered academically ready for the regular bilingual program. The students were in grades nine through twelve and represented five different language groups.

In the following lesson, which took place several months into the project, the teacher and students reviewed a homework assignment on acids and bases. (The students were previously introduced to the pH scale and pH paper in the context of an introductory unit on water quality.) The homework asked the students to answer such questions as: "Ammonia has a pH of 11 and baking soda has a pH of 8. Which is more basic? How do you know?" Because several languages were spoken in the group, the lesson was conducted in English. At the point we enter the transcript, the teacher had written on the board: "Ammonia has a pH of 11 and baking soda has a pH of 8." She asked the students for their responses to the question, "Which is more basic?":

Transcript 1

TEACHER: Which one did you put? Between ammonia and baking soda? Ammonia, ammonia? . . . You see ammonia is 11 and baking soda is 8, so we said ammonia is more basic. Ammonia, OK, alright. Ammonia. I don't see it in here, (pointing to a student's worksheet), I don't see it in here. Which one is more basic? Which one? Well, write it down there! OK, alright. Why? How do you know? Who can change that sentence for me (pointing to the sentence on the board) to give me an answer for, how do you know, for ammonia and baking soda, using almost the same words? How can I change that sentence? Nanzie, can you help me? OK, OK, go ahead.

(Nanzie goes to the board.)

TEACHER: Let's change it to answer that last question about baking soda and ammonia How can I change that sentence to answer, "How do you know about baking soda and ammonia? Because the pH number of - "

(Nanzie changes the sentence on the board to read "Because the pH number of ").

RONY: baking soda

TEACHER: Hold it! Hold it! "Because the pH number of baking soda . . . "

(Nanzie completes the sentence on the board by writing " baking soda is 8".)

TEACHER: Why are you saying what is the pH number? You're going to give it away.

STUDENT: 8!

RONY AND NANZIE (in unison): is lower -

TEACHER: I'm sorry. I'm sorry, "is lower than . . . "

RONY/NANZIE/SOFIE: "The pH number of baking soda . . . "

(Nanzie now has written on the board "Because the pH number of baking soda is lower than the pH number of baking soda.")

TEACHER: What are we talking about here? How are you going to do that? Don't you know? Maybe we should make this "higher" (pointing to the word "lower" in the sentence); if we say "higher" we have to say that the pH number not of baking soda, uh of - ammonia, we should put "ammonia" right here, so we can use "higher" over there. So don't change this. Yeah, put ammonia in there.

(Teacher explains what she wants done in Haitian Creole; the language of about half the students, including Nanzie.)

(Nanzie changes the sentence on the blackboard to read: The pH number of ammonia is higher than the pH number of baking soda.)

TEACHER: Alright! So what did we say? "The pH number of ammonia is higher, not equal, is higher . . . "

This is not an example of scientific sense-making. In fact, it looks a lot like conventional school science. All the action is organized around questions from the teacher and responses from the students. In addition, because this is a linguistic minority classroom, the attempt to teach science is confounded by the attempt to teach English too. The teacher's confusion can be seen in the homework question which frames the main discussion, "How do you know?" By this question, does the teacher mean to probe the students' understanding of how different pH readings relate to one another? Or does she intend to have students practice the comparative form in English, as is actually played out in the class? The consequence of her confusion is that neither intention is achieved, as Nanzie's own work eloquently attests (lines 22-23): "The pH of baking soda is lower than the pH of baking soda." The teacher becomes as confused as the students. In lines 25-34, she switches from "lower" to "higher" in order to escape the redundancy of Nanzie's sentence. In the process, she ends up doing all the constructive work herself (lines 27-28), telling the students which words to use and where to put them as if they were pieces in a puzzle.

In this example, we see the form science can take when the teacher has not articulated for herself *what* it is her students should be learning in science (i.e., what it means to do science), *how* they can best learn science, and *why* they should learn science. In our workshops we did not create the conditions that would foster this kind of deep reflection on scientific and pedagogical practice. As a result, the view of science as a sense-making practice we thought we were putting forward "remain[ed] alien, sound[ed] foreign in [her] mouth" (Bakhtin, 1981).

As a result of this initial experience, we radically restructured our work with teachers. We articulated our goal as follows: to create a community in which teachers can begin to (1) make sense of science conceptually, epistemologically, and pedagogically, and (2) interrogate science and their own deeply held beliefs about it and classroom practice from these points of view. Only by entering into this kind of critical dialogue, we recognized, can teachers begin to appropriate scientific ways of thinking and knowing to their own intentions. With this in mind, we now organize our work with teachers around three guiding themes: the teacher as learner, practitioner, and researcher (cf. Duckworth, 1987; Literacies Institute, 1989; Phillips, 1990). These themes highlight three interrelated perspectives that teachers must acquire in order to create classroom communities of scientific practice.

- As learners, teachers need to become involved with scientific phenomena and make sense of their own scientific activity.

- As practitioners, they need to experiment with and analyze new teaching practices derived from their activity as learners.

- As researchers, they need to make sense of their students' understandings—how they emerge and how they are expressed—and the relationship between their students' learning and their teaching practices.

In keeping with this reconceptualization of teacher development, we organized a seminar on scientific sense-making. We are currently working with eight teachers—five bilingual teachers, two ESL teachers, and a science specialist. These teachers, along with TERC staff (including a biologist), meet every other week for two hours after school and for two weeks in the summer.

The seminar began with teachers doing science; currently, the group is studying aquatic ecosystems. Most of the teachers started by investigating individual organisms (leeches, snails, planaria), although this focus gradually enlarged to include questions of community ecology and evolution. The teachers' investigations were organized around their own questions:

> Why do snails suddenly stop mating? Do they have a reproduction cycle?
> Are snails born with their shells? How does the shell develop?
> Why do baby snails seem to develop at different rates?
> How big do snails get? What is their life cycle?
> Why do snails poop so much? How important is poop and other "muck" to the ecology of a pond/aquarium? Does anything feed on poop?
> How do snails and other aquatic organisms relate to humans?
> Why do baby leeches stay attached to the mother for so long?
> If we put leeches in with snails, would the leeches decimate the snails?
> How do plants grow without a root system? How does duckweed reproduce?

The teachers pursued these questions at home and in the context of the seminar. Each teacher maintained a simple aquarium at home containing snails, plants, and other aquatic organisms (e.g., leeches, planaria, ostracods, etc.). They used hand lenses, stereoscopes, and microscopes to observe the organisms in their aquaria. They read books and articles on aquatic ecosystems, freshwater invertebrates, adaptation and evolution, constructivist teaching and learning, scientific practice and classroom discourse. In addition, each teacher kept a science notebook in which she or he recorded anything of interest, including data (i.e., observations, drawings, measurements), notes from readings, questions, plans for further investigation, and reflections on her or his classroom practice.

In the seminar, the teachers pursued their investigations and shared their work with their colleagues, collectively trying to make sense of what they were finding by puzzling over dilemmas, posing questions, developing evidence, designing investigations, interpreting data, and evaluating observations. As part of their practice, they also explored at an epistemological level what science is, how scientific knowledge is constructed, where theories come from, what constitutes evidence, the relationships among observations, theory and evidence, and the like. As the teachers began teaching science, the focus of the seminar expanded to include critical reflection on classroom practice and an explicit exploration of the connection between their work in the seminar and in their classrooms.

Pat: A Case Study

To illustrate best the character of the seminar and what it means to appropriate a new discourse, we focus on the experience of one teacher, Pat, and in particular on her talk at three different times during the year. We examine what Pat said and how she said it in order to uncover the beliefs and values about scientific practice on the one hand and about teaching and learning on the other in which her talk and action were grounded.

Pat is an ESL teacher with 25 years of experience. She co-teaches, with a Haitian bilingual teacher, a combined 5th-6th grade of Haitian students and teaches ESL to a combined 7th-8th grade. Pat describes her science background as typical of most elementary grade teachers educated in the 1960s. She took a few courses in college to meet degree requirements and taught science in grades 3 and 6, mostly, as she put it, "from the book." She feels that it was through teaching science that she did most of her learning in science.

January 9, 1992, Meeting

We begin with a transcript from a seminar meeting that took place on January 9, 1992. The group had met six times before for a total of 14 hours. At this point in the year, group members were for the most part working as individuals; there was not much give and take about what they were doing and not much co-construction of scientific meaning. The January 9 meeting was the first after the Christmas break. During the break, the teachers had pursued their scientific questions at home, observing snails and other aquatic organisms, and reading related texts. To open the meeting, Beth, one of the researchers, asked each teacher to share briefly their observations with the group. Pat began:

Transcript 2

PAT: I would like to know if any one identified, or how one, how people identified the snails that we have. I had thought it was a Helisoma from the pictures in here, did anyone else?

LAURA (science specialist): Yeah, but I didn't key mine out.

PAT: What did you think?

LAURA: I remember looking at those pictures but I didn't get really involved in trying to figure out exactly what kind of . . . I sort of figured out what it wasn't in a way, some things that it couldn't be, but I never did really key it right down.

BETH: What, Pat, made you particularly interested in identifying the kind of snail?

Pat: Uh, there are so many different types and from the reading it said you can make it if you look at the snail's, um, if the opening is on the left side it is one kind of snail and if it's on the right side it's another kind of snail. And, and I was trying to draw, to draw it, and it just, it was identified. I would like to identify it. It's like, it's like naming somebody, you know, giving a name to something, I, I like doing that.

Beth: Did you find that your observations fit with the kinds of things you were finding in the book?

Pat: Mmmhmm.

Beth: or

Pat: and also the reading was interesting to me. You know, I was able to look for the beating heart and the teeth and so forth so, it just, it helped to guide me as far as, um, looking at it, and trying to find out something and seeing how it worked.

Gilly (biologist): Could you see the teeth?

Pat: Yes, the little red thing.

Gilly: Yeah?

Pat: Hmmhmm.

Gilly: Yeah?

Pat: Hmmhmm. In some of them.

Beth: What, what kind of red thing? I mean what details. . . ?

Pat: Well, there are lots, you know uh there are thousands of teeth and the teeth break off and then they grow more teeth so you know they, they're back and forth, I think, I guess I have to look again (referring to her notebook) . . . the *radula*. Ahh, it moves back and forth very rapidly and grinds the food to clean it in the roof of this . . . *buccal cavity*. I learned all sorts of vocabulary words. (Laughs.) That means stomach. (Laughs.) There are so many words I didn't know that I had my dictionary next to me looking up words.

Beth: Did you ever see a snail eating?

Pat: Sure.

Beth: Using its mouth?

Pat: Mmhmm, mmmhmm. You could actually see it with the hand lens or, ah, it was kind of munching and that's what it even says, it's munching. And then with all those teeth, there are thou . . . (reading in notebook) the teeth may number in the thousands! (. . .) Pretty interesting. Who knows? (Laughs.)

This episode is striking in the way that Pat, through her talk, revealed her initial stance toward science and her perception of herself as a learner. She reported only those things for which she had found authoritative validation (i.e., in an external scientific source). When asked to report on the science she had done over vacation, for example, Pat talked mostly about a passage on snails she had read in a scientific reference manual on invertebrates. She shared with the group bits of what she had learned from the book (lines 32-38) and, referring to her notes, used several technical words (radula, buccal cavity) to explain how snails eat. Significantly, her first move in the conversation (lines 1-3) was to see if others in the group, specifically Laura, the science specialist, had identified the snail. Through her question and gaze, Pat was seeking confirmation from a person in the group she deemed more qualified than herself to make scientific claims.

Pat was quite clear about her reasons for using texts as references. In lines 21-24, she explained how the book helped orient her observations ("You know, I was able to look for the beating heart and the teeth and so forth so, it just, it helped to guide me as far as, um, looking at it, and trying to find out something and seeing how it worked."). But Pat's personal observations comprised only a small part of what she chose to tell the group. In fact, she shared only two things she herself had seen (line 26, "the little red thing" referring to the snail's mouth, and lines 42-43, "it was kind of munching," referring to the snail's chewing action), and these only when prompted first by Gilly (the biologist) and later by Beth. Interestingly, this imbalance in Pat's talk between personal observation and research from authoritative sources did not accurately reflect the work she had done during the vacation. In her science notebook for this period, she filled *nine* pages with personal observations of snail anatomy and behavior.

Pat is like many of the teachers with whom we have worked who are initially unsure of the importance, accuracy, and validity of their own scientific work. Reflecting traditional school practices and the larger society's values, they tend to place greater stock in the words of an authority (i.e., a text, an expert, the scientific canon) than in their own sense-making. In her report, Pat emphasized what she had learned from books because, at this moment in the seminar, she placed more value on what authoritative texts said than on what she herself had seen. They carried more weight than did her own hours of work. In fact, in lines 42-43, Pat revealed just how important external, authoritative validation was to her when she said, "You could actually see it with the hand lens or, ah, it was kind of munching and that's what *it* (our emphasis) even says, it's munching." The "it" was the book she had been reading. Pat's focus on identifying her snails (lines 2-3: "I thought it was a Helisoma . . . ") and on acquiring scientific vocabulary also suggests that she was trying to put herself in contact with the scientific canon and the standard scientific register.

From a Bakhtinian perspective, Pat was struggling to appropriate scientific words, to sound scientific. As she told us later, at this point she did not really understand what it meant to ask a scientific question. In fact, in the transcript Pat called attention to her own uncertainty —about herself as someone who can do science and about the validity of any knowledge she herself had constructed—when, in the last line of the transcript, she rhetorically asked, "Who knows?"

As we see it, the struggle for Pat, as for all learners, lies in appropriating "words" (broadly construed to include ways of making sense, valuing, acting, and the core concepts underlying a discipline) for the purpose of constructing scientific meaning. In this episode, Pat used technical terms for descriptive purposes and, through them, tried to make contact with scientific knowledge and practice. She was, in effect, attempting to set up fixed, definitional equivalence relations (such as those found in dictionaries) between things and their names. As Wertsch (1991, p. 116) points out, those who use this practice often assume that "meaning is grounded in closed, exhaustive systems of decontextualized sign type-sign type relationships, or 'literal meanings.'" As a successful learner, Pat is a skilled user of books. Similarly, as an ESL teacher, Pat believes strongly in the power of words; a principal function of her job is to teach new words to her students. Knowing the words of a domain is one of the ways in which she assesses competence—her own and her students'—in that domain. Her use of texts and technical vocabulary is, therefore, highly strategic and, it turns out, effective. Through this strategy, she bridged from familiar, literalist ways of knowing to more interpretive, scientific ways, as the next two transcripts show.

February 13, 1992, Meeting

The next transcript is taken from a meeting that occurred on February 13, 1992. Between the January and the February meetings, the members of the seminar investigated various aspects of snail life, including reproduction, development, and feeding habits. During the seminar immediately preceding the February 13 meeting, Gilly, the project biologist, looked at the contents of a petri dish and found a leech in it with many babies attached to its stomach. Pat immediately showed interest in the leech and decided to take it home for observation. Between meetings she observed the leeches along with the snails she had at home, and filled 15 pages of her notebook with observations of leech and snail behavior (e.g., their movement, anatomy, eating and mating habits).

At the start of the transcript, Pat took her turn to share her observations from the previous two weeks. As she did so, a jar containing the leeches was passed among the other seminar members. As she described how one of the snails eluded the adult leech by going above the water line, Sylvio and Laura, two teachers, were looking at the jar and seeing exactly what Pat was describing.

Transcript 3:

PAT: Yeah, an interesting thing is that I had those same leeches in a petri dish for a few weeks and when the mother, the mother must have had, I don't know how many, she must have had more than 15 babies attached to her underbelly because we kept seeing them drop off at, if it were put into heat, if I held them up to the light to look at them on the slide a few would come off, we saw them come off here but none were living in the petri dish and I actually saw twice the large leech with a baby leech in its mou[illegible], it was going in and out and then finally it was sucked in so, and I could find no baby leeches living in the petri dish, so I think that the parent, you know, the adults, were eating the small ones which made me think they must be hungry so I fed them. I took a larger snail but I killed the snail because they couldn't, the snail was able to knock the leech off so that it couldn't get into it to eat. Also the snail was so smart that it would go, the leech would be attached, the snail would go above the water line so the leech had to drop off. So you know they *knew* they were after them. In fact, Sylvio [Pat's teaching partner] was asking why are those snails up on the top of the jar lid so much and I wondered why. Well, they were smart. They tried, they didn't want to be eaten. But once we put them into the larger, the uh, the large, the deeper water and, um, and I gave them to Sylvio to keep, uh, the um, the babies are growing now so– They ate snail and now they don't have to eat the babies apparently. But that's a question. I want to take, you all say you have some more leeches? So the question is, I'll keep some in a petri dish with an adult, adults, without foo-, well with the snails to eat, see if they eat them then. And then still, like this, it could be the deeper water, it could be, I should have three actually.

ANN (a researcher): Do you want to take some home tonight?

PAT: Yeah.

Pat's talk was markedly different than in January. In her talk she intertwined observational, conjectural, and experimental modes in one unbroken string of reflection. She was thinking through her talk, ending her turn by spontaneously formulating an experiment, the goal of which was to deepen her understanding of the conditions under which adult leeches eat their young.

Perhaps most striking, in contrast to the January transcript, Pat now spoke as an authority. She was not talking *through* the texts she had read, seeking their authority either to guide her observations or to confirm them. Rather, she spoke distinctly as the *author* of her own observations, discoveries, conjectures, and experiments.

Her report took the form of a story, in the sense intended by Medawar (1987) and Ochs et al. (Ochs, Taylor, Rudolph & Smith, 1992). It is a kind of theory with a problem-to-be-solved at its core: how to keep the adult leeches from eating their young. Pat did not just report her observations as a set of events; rather she theorized them, explaining how her observations led her to particular hypotheses (lines 7-11) and beliefs about how the organisms interact (lines 13-19), then to particular actions or experiments (lines 13-19). An example of this theorizing discourse is found in lines 9-11: " . . . I could find no baby leeches living in the petri dish so I think that the parent, you know, the adults, were eating the small ones which made me think they must be hungry so I fed them." But she found that this plan didn't work because the snail eluded capture (lines 13-15).

Her last move was unplanned (Ochs, 1979), following an explanation she marked as tentative, not yet supported by what was satisfactory evidence to her (lines 21-22: "They ate snail and now they don't have to eat the babies *apparently*."). She immediately recognized one and possibly two questions implicit in her account (the conditions under which leeches eat their young; the conditions under which baby leeches can survive). Finally, she proposed an experiment intended to evaluate her tentative explanation (lines 22-23: "But that's a question. I want to take –"). Thus, she opened her own explanation to a possible internal challenge, mirroring the kind of criticism about which Medawar wrote. The quest for naming and identification characteristic of her talk in January gave way in February to theory building and criticism. Perhaps most important, Pat now had an answer to the "Who knows?" with which she concluded her turn in the first episode.

February 27, 1992, Meeting

Two weeks later the seminar met again. During those two weeks, Pat gave the leeches to Sylvio, her teaching partner, for observation and caretaking. Pat herself observed snails and several snail egg masses (jelly masses with several eggs lodged in them). The week before, Ann reported that a teacher in another seminar had witnessed a dramatic increase in the snail population in her tank (150 by her count). This fact figures in the following episode.

Transcript 4

PAT: Well, my, my three snails weren't mating so I, I put them into
another container and, also the baby, I should have had 150 baby snails
by this time like this other woman and they weren't, I mean they were
hatching, they were coming out and just stringy masses around but not
many snails. So, I've been, I was looking in my jar to see what could
have eaten, you know, the snails. I figured they were being eaten
somehow and there are, I brought in a few little animals, you know, that I
looked at but, um, then I also put some baby, two, some baby snails in
a, those, what are those little, petri dishes with some of those
animals and left them in for a week and they haven't been eaten. So I,
I don't know what's happ– You know, I still have that jar and the snails
aren't in there so the water is becoming murky. It's a bit murky, but,
you know, it's kind of gross right now. But, um, I don't know what's, why
those snails, those baby snails aren't, are not living, so many of them, but my
other snails are all alive.

ANN: I'll tell you one thing that I've noticed in our tanks down here is
that, um, the snails seem to be laying a lot of eggs in the roots of the

duckweed, you know, that hang down. And the eggs look fine for a while and then all of a sudden they get cloudy and they get kind of fuzzy around the edges. And we took some of the eggs out and looked at it under a hand lens and under a stereoscope and they seemed to be covered with little tiny creatures. Somebody has said that they look like Paramecium. Somebody else has said that they look like, I mean, I have no idea what they are, but they are these little white creatures. Oh, at one point they looked like stentors, they were all over them. They looked just like a huge breeding ground for stentors and so I think that what's going is, it's exactly what you said, something else is–

PAT: I figured last night

ANN: There's something out of balance.

PAT: that, that, that, that maybe those things, those little things that are eating away at the other things are multiplying at a faster rate than the snails or something like that, you know what I mean? That the balance, it's out of balance, something's out of balance.

ANN: Yeah, hmmhmm. Whatever used to be eating the stentors and keeping them, if they're the ones who are doing the, eating the eggs, whatever used to be keeping them in check, isn't there anymore.

BETH (researcher): Although this issue of

ANN: maybe

BETH: in balance and out of balance

ANN: yeah.

PAT: That's interesting.

BETH: is kind of a weird one, maybe it's not out of balance–

RACHEL (bilingual teacher): Maybe there aren't supposed to be so many snails.

Ann: Yeah

SOMEONE: That's right.

RACHEL: and in the other tank where there's 125 snails, that one's out of balance!

ANN: That's right! That's right.

PAT: Think of how many cockroaches are killed, just imagine, and flies. All the larvae that's laid every winter and then in the spring. If some of those things aren't killed, wooo!

LAURA (science specialist): And you know that, that's even true for the tank in my room when I think about it. You know, I complain about how many snails are in that tank but when you, when you see how many egg masses get laid on the side of the tank and if there's, you know, 20 or 30 baby snails in there sometimes, I pulled 12 egg masses out of there today alone.

PAT: Oh my gosh!

LAURA: And then, you know, but it's not as crowded as it should be because if all of those things hatched and grew up–

PAT: I know there aren't even that many snails–

LAURA: they should take over everything! And they're in there a lot but not anywhere as much as they should be according to what's been laid.

PAT: Does that newt eat, eat snails?

LAURA: I don't think so.

PAT: Snails eat other snails, I saw.

RACHEL: Yeah, snails eat other snails.

LAURA: I have a lot of, uh, planarias in there now, I noticed, and I think they're doing a number on the snails.

PAT: Uh huh.

JOSIANE: They're mean.

RACHEL: Yeah? What do they do?

PAT: Do you think that's what was eating your snails?

As in the previous seminar, here Pat told another story with two problems at its center: Why the adult snails were not mating and why she did not have more baby snails than she did. She again combined observational, conjectural, and experimental modes: (lines 5-10) "I was looking in my jar to see what could have eaten, you know, the snails. I figured they were being eaten somehow . . . "; (lines 8-10) "I also put some . . . baby snails in . . . petri dishes with some of those animals and left them in for a week and they haven't been eaten." The difference here in comparison to the previous transcript lies in the fact that Pat was not able to solve her problem. As a result, in lines 13-15, she repeated the central problem at the end of her first turn: "But. . . I don't know . . . why those snails, those baby snails aren't, are not living, so many of them, but my other snails are all alive." Ann interpreted this repetition as an invitation to help Pat think through her problem.

The rest of the episode is a kind of dialogic storytelling that contributes to the co-construction of a theory (Ochs et al., 1992). Sparked by Pat's dilemma and Ann's analogous observation, several members of the seminar began to construct a theory to explain Pat's observations and, by extension, their own. In the process, they not only worked through what might account for Pat's observations, but they also helped Laura, the science specialist, see the tank she had in her classroom in a new light.

Each participant in essence functioned as a co-author (Duranti, 1986; Ochs et al., 1992). Ann's story (lines 16-28) reinforced Pat's own observations. Pat overlapped with Ann just as Ann put forward the idea of balance as being somehow important in explaining the situations she and Pat had observed (lines 26-34). Pat elaborated this idea in her own terms: "I figured last night . . . those little things that are eating away at the other things are multiplying at a faster rate than the snails, or something like that, you know what I mean?" Interestingly, she appropriated Ann's term "balance" only after she had articulated her own idea. Unlike the January episode where she relied on the words of texts, Pat chose to say what she thought in her own words first. Ann replied in terms of her own example.

Beth then took a turn (lines 38-43) and posed a challenge to the budding theory, reorienting the frame for its discussion: "Although this issue of 'in balance and out of balance' is kind of a weird one, maybe it's not out of balance–." In lines 44-48, Rachel, a Spanish bilingual teacher, then operationalized this in terms of Pat's dilemma: "Maybe there aren't supposed to be so many snails and in the other tank where there's 125 snails, that one's out of balance!" Pat followed with an analogy to cockroaches and larvae (lines 50-52). At this point, lines 53-64, Laura, the science specialist, reflected on the tank she had been maintaining: "And, you know, that, that's even true for the tank in my room when I think about it . . . " Laura clearly marked her utterance as a new thought ("when I think about it . . . "). In this instant, she understood the dynamics of her tank differently than before: "You know, I complain about how many snails are in that tank, but when you, when you see how many egg masses get laid on the side of the tank and if there's, you know, 20 or 30 baby snails in there, I pulled 12 egg masses out of there today alone, and then, you know, but it's not as crowded as it should be because if all of those things hatched and grew up, they should take over everything! And they're in there a lot but not anywhere as much as they should be according to what's been laid." The group, through co-construction of a theory, led Laura to this new perspective. The conversation continued as the group tried to figure out exactly what might be keeping the snail population in check. They began by considering the impact of other organisms and, then, prompted by another member of the group, they considered the contribution of chemical factors such as pH.

We see in this episode a particularly rich illustration of the notion that theory building is an interactionally achieved sense-making activity (Ochs et al., 1992; Sacks, 1972, 1974; Schegloff, 1972). Pat's dilemma became a shared dilemma. In the process, the group theorized about it, using analogies, accounts of others' observations, and shifts in perspective on the concepts being theorized.

The foregoing transcripts show that the seminar evolved into a community of science practitioners. Furthermore, the teachers' joint scientific work became the basis for a rethinking of classroom practice. Over time, their inquiry came to include, in addition to their own science, analysis of their teaching practices and how these practices relate to students' learning.

Building Scientific Sense-Making Communities in the Classroom

Through their reflective practice, the teachers are constructing a view of science as a socially constituted, meaning-making activity that *includes* rather than excludes linguistic minority children. This new view of teaching and learning is rooted in the teachers' own appropriation of scientific ways of thinking and knowing. In conclusion, we illustrate one of the ways the teachers are building on their own scientific inquiry and reflective practice to create scientific sense-making communities in their classrooms.

Three months after the group's discussion of snail reproduction and survival rates (Transcript 3), the teachers began to critique their teaching practice. They felt they had succeeded in creating classroom communities in which children's scientific questions were valued. However, they were concerned that they did not always know what to do with those questions. In particular, they felt they did not know how to help shape students' questions into scientific investigations. An event in Pat and Sylvio's classroom provided the group with a context for exploring this problem directly.

A student, Jimmy, had written the following question in English in his science notebook as he was observing snails: "Why little animals can make babies? It too little to make baby." This question became the focus of the seminar for several weeks. Among themselves, the teachers explored the possible meanings of Jimmy's question and uncovered unexpected complexities. For example, they realized that Jimmy's use of "little" was ambiguous. By "little," did he mean age, size, sexual maturity? Intrigued by their own interpretations of Jimmy's question, they designed an investigation to study the size and age at which snails reproduce. From their study, they concluded that snails 5 mm in length and up can reproduce. They were careful, however, to note that their data for shorter lengths were not necessarily conclusive (i.e., possible sampling problems; duration of study too short).

In parallel, Pat and Sylvio engaged their students in discussion about the meaning of Jimmy's question. The class then used this discussion as the basis for designing a year-end investigation of the question: At what size do snails make babies? The students designed their investigation so that each student had snails of one size (ranging from 1mm to 9mm) in a petri dish. They discussed the importance of providing each with a suitable environment and comparable food supply. They agreed to observe the snails daily to see if any had produced egg masses. They measured the size of each snail once a week to see if they had grown enough to require "reclassification" (i.e., transfer to another petri dish containing snails of the next larger size). In the end, they decided that on the basis of their data, they could safely conclude that snails 7mm to 9mm in length are capable of reproduction. However, they ran into difficulty interpreting their data for shorter lengths because some students had mixed snails of different sizes. For example, they observed that a dish with snails 3mm and 5mm in length had egg masses but decided to disqualify it because it violated the design criteria they had established for their study.

During part of a two-week summer seminar, the teachers continued to reflect on this episode, analyzing transcripts of their own talk about Jimmy's question as well as transcripts from Pat and Sylvio's classroom. Through reflection on their own scientific practice and that of the students, the teachers co-constructed a theory of scientific sense-making that brought to light fundamental issues in teaching and learning. For example, they confronted the challenges involved in understanding what students mean by what they say. They realized that surfacing the tacit theories, beliefs, and assumptions underlying students' questions is integral to scientific practice and to shaping scientific investigations in the classroom. They further realized that by making these dimensions of students' thinking explicit, teachers help students specify the parameters of the investigation they need to undertake in order to understand the phenomenon in question. The teachers' reflections also led them to think more deeply about how to orchestrate scientific discussions, the effect of teacher revoicings, ways to investigate the different kinds of questions children ask, how to assess student learning, and ways to socialize students into more formal genres of scientific reading, writing, and talking.

We believe that in order to rethink teaching and learning in these ways, the teachers had to become participants in a community of scientific practice and appropriate scientific ways of thinking and knowing to their own intention. Building on this experience, they explored with their students ways to create sense-making communities in their classrooms. Through participation in these communities, their students, too, are beginning to develop an insider's view of science (Rosebery et al., 1992). Pat spoke to this point during the summer seminar:

> [I]t seems to me that . . . you're teaching a certain, or they're learning, or you're learning together a certain way of being, of making sense, or of learning how to be scientific, that children never did before, that none of us probably did before in class. So you have microscopes and you have pond water and you have all these things that you've never seen before, all this wonderment around you, and you're able to pick and choose, to ask questions, not have them answered but go looking for evidence, setting up investigations . . . .At least maybe in our classrooms they've learned a way of asking questions . . . .You know, there's this certain way of being in the world that they're learning, that's what I think.

In this paper we have sought to illustrate the complexities of the process into which we, Pat, the other teachers, and their students have entered, namely, to define a new perspective on scientific practice in the classroom that admits diverse sense-making practices, carries with it more egalitarian values, and allows linguistic minority students to acquire the mainstream literacies they need to succeed in school and beyond. When Pat speaks of students "learning a certain way of being in the world," she is describing a new kind of relationship between students and science, one that is distinctly different from that enacted in conventional school science. Moreover, she sees herself participating in a new relationship with her students, as they jointly work out what it means to be scientific. From this perspective, the transformation of science education into a practice that *includes* rather than *excludes* linguistic minorities demands more than new curricula, new teaching strategies or, more broadly,"trickle down" reform strategies. Rather, we believe that the remaking of science education into a more egalitarian sense-making practice entails deep transformations of identity for teachers and students alike, transformations that empower them to think, talk, and act scientifically.

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