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ABSTRACT

This paper argues for a rethinking of what it means to "do science" in language minority classrooms by putting forward a view of science as a sense-making practice. Before outlining a sense-making perspective on scientific practice, some familiar images of what science is like in many classrooms are invoked in order to lay out a few critical connections among teaching, learning, and assessment. Two examples are provided, one descriptive of science in many mainstream classes, and the other of science in a Chinese bilingual program in California. The following questions are explored: What is the purpose of doing science in language minority classrooms, to learn science or to learn English? Is there an alternative to common practice? and What are the implications of such an alternative for assessment? The sense-making alternative to traditional practice is discussed as well as possible contexts and roles of assessment that emerge in a sense-making culture in language-minority classrooms. Implications of this view for improving science education and assessment for language minority students, paying particular attention to issues of teacher development, are explored. Responses to the paper by Ron Rohac and Sam Lin Tsang are appended. (VWL)

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Science Education as a Sense-Making Practice: Implications for Assessment

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In this paper, we argue for a rethinking of what it means to *do science* in language minority classrooms by putting forward a view of science as a sense-making practice. We then explore the implications of this view for assessment. But before outlining a sense-making perspective on scientific practice, it is helpful to invoke some familiar images of what science is like in many classrooms in order to lay out a few critical connections among teaching, learning, and assessment. Two examples follow, one descriptive of science in many mainstream classes (although the example itself is drawn from a science class outside of the United States) and the other of science in a Chinese bilingual program in California.

> I once witnessed a marvelous science lesson virtually go to ruins. It was a class of young secondary school girls who, for the first time, were let free to handle batteries, bulbs, and wires. They were busy incessantly, and there were cries of surprise and delight. Arguments were settled by "You see?", and problems were solved with, "Let's try!" Hardly a thinkable combination of batteries, bulbs, and wires was left untried. Then, in the midst of the hubbub, the teacher clapped her hands and, chalk poised at the blackboard, announced: "Now, girls, let us summarize what we have learned today. Emmy, what is a battery?" "Joyce, what is the positive terminal?" "Lucy, what is the correct way to close a circuit?"...And Emmy, Joyce and Lucy and the others deflated audibly into silence and submission, obediently copying the diagram and the summary. What they had done seemed of no importance. The questions were in no way related to their work. (Elstgeest, 1985:36-37)

The problem Elstgeest describes is the disjunction between learning and teaching, between what students learn when they engage phenomena directly and what teachers (or curricula or tests) think they should be -- or are -- learning. For a variety of reasons, teaching in many cases is not connected to students' learning, to the sense students make of the world around them. In Elstgeest's example, in fact, the teacher's questions -- which function as a form of evaluation -- act to undermine rather than encourage the students' learning. Focusing narrowly on definitions and correct answers, the questions ignore the students' scientific explorations and efforts to make sense of phenomena.

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In language minority classrooms, science -- when it is taught at all -- is often even further reduced (cf. Moll, in press), as illustrated in the following example:

> 9:10 Science T (or prep T) comes in to teach science. She hands out a solar system puzzle and tells students to do it on their own because it is like a quiz. D (NES: Non English Speaking) is playing around. He can't do the handout, so Prep T takes it away. He begins working on his penmanship handout.
>
> The crossword puzzle is too difficult for the NES and LES (limited English speaking) students. I begin working with C (NES) first by explaining the definitions in Chinese (e.g., the largest planet or the ringed planet). He can't recall the word on his own even if he knows the meaning. So I get the encyclopedia volume on the solar system for him to use as a reference book. He is able to answer the first few questions on the crossword puzzle on the planets but gets stuck on the more difficult words. Furthermore, he can't even understand the definition or clue words for the puzzle. (Guthrie, 1985:161-162)

On the surface, at least, this case looks very different from the Elstgeest example and, in some crucial respects, it is. Whereas in the Elstgeest example the students actually got their hands on batteries, bulbs, and wires, in this case the crossword puzzle exercise is abstracted out of any meaningful context of scientific activity. Further, in the second example, science is confounded with English language development. The focus of the exercise is on definition and naming. Students in a class like this memorize the definition of the word "hypothesis" but never experience what it means to formulate or evaluate one.

But, in other respects, Guthrie's example is not so far from Elstgeest's. Underlying the pedagogical approach in both is a view of science as the accumulation of facts, definitions, terminology, and correct procedures. Teachers pose the questions and, more frequently than not, provide the explanations. The Elstgeest example is particularly instructive in this regard because it has at its center hands-on exploration. But hands-on science, it turns out, is not enough. In the absence of a framework for understanding students' scientific sense-making, even the best hands-on curricula can become the occasion for knowledge transmission. It is striking, too, that in both cases teaching doubles as assessment. In the Elstgeest example, the teacher queries the students to see if they have learned the right things: the components of a battery, how to close a circuit. In the Guthrie example, the exercise is set up as a quiz, to assess how much technical English vocabulary the students have acquired.

These images of science are widespread. Recent national and international assessments (Mullis & Jenkins, 1988; McKnight et al.,

1987) and calls for reform (AAAS, 1989; Symansky & Kyle, 1990) testify to this fact. More important are the questions raised by these common practices:

- What is the purpose of doing science in language minority classrooms, to learn science or to learn English?
- Is there an alternative to common practice?
- What are the implications of such an alternative for assessment?

In this paper we will explore these questions. Drawing on concrete examples of classroom science, we will elaborate an alternative to traditional practice which we refer to as scientific sense-making and discuss possible contexts and roles of assessment that emerge in a sense-making culture in language minority classrooms. We also explore the implications of this view for improving science education and assessment for language minority students, paying particular attention to issues of teacher development.

Why Do Science?

In bilingual programs this question looms large. In many cases, science is not taught at all. In those cases where it is a part of the curriculum, it is often seen as a context for learning English. Its intrinsic value as an academic discipline, as a way of thinking and knowing, is either ignored or not recognized.

As we have argued elsewhere (Warren, Rosebery & Conant, in press), a *pluralistic* view of language and literacy (cf. Literacies Institute, 1990) not only reframes the problem of what it means to learn science but helps us better understand the relationship between doing science and literacy development. According to this view, knowing a language entails knowing more than *the* English language or *the* Spanish language or any other language. Each language is really many languages, a set of possible discourses people use to communicate with one another in their daily activity (Bakhtin,1981). These discourses in turn each constitute a set of beliefs and values in terms of which one speaks, thinks and acts (Gee, 1989). The particular discourse worlds we inhabit depend on our history, the books we have read, the people with whom we have talked and from whom we have learned, the social circles in which we have moved, our economic class, our generation, our epoch, the institutions (church, political party, schools, societies) to which we have belonged, and so forth (Booth, 1986). As the Soviet theorist, Mikhail Bakhtin (1981:291), explains:

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At any given moment of its historical existence, language...is heteroglot from top to bottom: it represents the co-existence of socio-ideological contradictions between the present and the past, between differing epochs of the past, between different socio-ideological groups in the present, between tendencies, schools, circles and so forth, all given a bodily form. These "languages" of heteroglossia intersect each other in a variety of ways, forming new socially typifying "languages."

The idea that language is heteroglot poses some difficulties for both our common sense and technical uses of terms such as language (as in "learning the English language") and literacy. In both senses, these terms are often used to suggest a capability that is unitary and univocal rather than pluralistic and multivocal (although the varied definitions of literacy that abound in the literature are perhaps a clue to its inherent diversity). In the same vein, language and literacy often are defined in terms of mastery of certain general skills -- reading, writing, arithmetic skills -- rather than in terms of mastery of whole systems of meaning and practices, each involving a set of beliefs and values or, in Bakhtin's term, an *ideology.*

From within this sociocultural perspective on language and literacy, then, we do not view science as a context for developing English language skills. Nor do we define scientific literacy as the acquisition of specific knowledge ("facts") or general skills (e.g., observation, inference) or correct mental models. Rather we understand scientific literacy to be a socially and culturally produced way of thinking and knowing, with its own sense-making practices, . own values, norms, beliefs, and so forth. In this light, when students learn science, they are *appropriating* socially mediated ways of knowing, thinking, acting and using language (both first and second languages) to construct scientific meanings.

The task facing the second language learner -- and, specifically, in this culture, the learner of English -- is therefore enormously complex. 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 school yard, doing mathematics, doing science, doing history, and so on (cf. Gee, 1989; Michaels & O'Connor, 1991). The notion of appropriation is key because it casts the learner as someone who is trying to find ways to take the sense-making practices of science, for example, and make them his or her own, tuning them to his or her own intention, his or her own sense-making purposes. As Bakhtin (1981:293-294) explains, appropriating a new discourse is a difficult process:

(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.

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, 1989). 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 their teachers) participate. As Michaels & O'Connor (1991:11) explain,

> This conception of literacy has strong implications for how we think about cultural diversity and the knowledge that students bring with them from home. Each child in this society learns culturally appropriate ways of using language and of taking meaning from written texts in the early years at home. Cultural groups in this society have sophisticated ways of integrating the written language around them into their daily social life. However, ways of using oral and written language are closely tied to culturally different ways of interacting with others and with culturally different values and attitudes. Some children have home-based ways of using language that are more closely related to the ways in which language is used in schools than are the home-based practices of other children.

For language minority students, the appropriation process can therefore be more arduous than for other students, for the distance they must travel between discourse worlds -- ways of organizing an argument, interpreting questions -- is often far greater. As research has shown (Au, 1980; Au & Jordan, 1981; Michaels, 1981; Mohatt & Erickson, 1980; Philips, 1972), conflicts between school-based ways of using language and minority students' home-based practices can create barriers that limit minority students' access to the discourses that are needed to achieve in this society (Heath, 1983; Michaels & O'Connor, 1991).

Within the framework we are putting forward here, the key question then becomes: In what ways can language minority children be enculturated into the community of scientific discourse? What does it mean to do science? These are the questions to which we now turn our attention.

Science as a Sense-Making Practice

A new conceptualization of learning is emerging in the research literature (Brown & Campione, in press; Brown, Collins & Duguid, 1989; Lampert, 1990; Resnick, 1989; Schoenfeld, in press-a, in press-b). Drawing heavily on Vygotsky (1978, 1985) and on anthropological perspectives on learning and cognition (Geertz, 1973, 1983; Lave, 1988), this literature views learning as an inherently cognitive <u>and</u> social activity. The child appropriates new forms of discourse, knowledge, and reasoning through his or her participation in socially defined systems of activity. 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 a particular discipline.

Central to this 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 "cannot make up meanings in any old way." Rather, they build up ways of knowing, talking, acting, and valuing, which help to constrain the construction of meaning within the discipline. Within this 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, 1988; Resnick, 1989; Rosebery et al., 1990; Rosebery et al., in press; Schoenfeld, in press-a, in press-b; Warren et al., 1989).

What, then, is the nature of scientific practice? For the Nobel Laureate, scientist, Sir Peter Medawar (1987:129), scientific sense-making is a 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.

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. First, he challenges the belief that science, at bottom, is the discovery of a reality that exists "out there," pregiven but hitherto concealed (cf. Latour & Woolgar, 1986). Secondly, he challenges the belief that scientists work according to a rigorously defined, logical method, known popularly as The Scientific Method. And thirdly, through his emphasis on story building, 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 and construction -- 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 "out there." Further, he insists on the dialogic quality of scientific activity: fact and fancy, invention and criticism interacting.

Contemporary sociological and anthropological 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 is really the end result of the practice of a group of scientists whose goal is to eliminate as many alternative interpretations as possible to their account of the phenomena being studied. Rather than the orderly, logical and coherent process that is described in science textbooks as The Scientific Method, actual scientific practice entails making sense out of frequently disorderly observations and negotiating among alternative interpretations. Through graphs, notes, statements, drafts of papers, and published papers, accounts are constructed, claims are negotiated, analogies are sought, arguments are put forward and defended against attack, and objections are anticipated (Latour & Woolgar, 1986). As Latour and Woolgar show, scientists claim merely to be discovering facts but close observation reveals that they are 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.)

Through our work with bilingual teachers and students (Rosebery et al., in press; Warren et al., in press; Warren, Rosebery, Conant & Barnes, 1990), we are attempting to elaborate an approach to science teaching and learning that supports the development of scientific sense-making communities in the classroom. The basic idea is to create a community in which what the students think—the sense they are making of the world -- rather than what the text or teacher thinks is at the center of the class activity. This approach entails a radically different orientation to teaching and learning than that found in traditional classrooms, one in which students construct their scientific understanding through an iterative process of theory building, criticism and refinement organized around their own questions, ideas, and data analysis activities. Fundamentally, the idea is to place question posing, theorizing, and argumentation at the heart of students' scientific activity. Students explore the implications of the theories they hold, examine underlying assumptions, formulate and test hypotheses, develop evidence, negotiate conflicts in belief and evidence, argue alternative interpretations, provide warrants for conclusions, and the like. Conceptually, they investigate their own questions and the beliefs or theories from which they derive; epistemologically, they explore relationships among truth, evidence, and belief in science. They, in short, become authors of ideas and arguments (cf. Lampert, 1990).

In addition, students' inquiries are collaborative in nature, just as is most professional scientific activity. The emphasis on collaborative inquiry reflects our belief, building on Vygotsky (1978), that robust knowledge and understandings are socially constructed through talk, activity, and interaction around meaningful problems and tools. Collaborative inquiry provides direct cognitive and social support for the efforts of a group's individual members. Students share the responsibility for thinking and doing, distributing their intellectual activity so that the burden of managing the whole process does not fall to any one individual. The distribution and sharing of intellectual responsibility is particularly effective for language minority students, for whom the language demands of tasks are often overwhelming and can often mask their abilities and understanding. In addition, collaborative inquiry creates powerful contexts for constructing scientific meanings. In challenging one another's thoughts and beliefs, students must be explicit about their meanings; they must negotiate conflicts in belief or evidence; and they must share and synthesize their knowledge in order to achieve a common goal, if not a common understanding (Barnes & Todd, 1981; Brown & Palincsar, 1989; Hatano, 1981; Inagaki & Hatano, 1983).

Students' investigations are also interdisciplinary; science, mathematics and language use (talk, reading, and writing in both first and second languages) are intimately linked. Mathematics and language are recognized as essential tools of scientific sense-making, which stands in sharp contrast to traditional schooling in which science is separated from math and the role of language in each is hardly acknowledged (or, as in the case of many bilingual science programs, the relationship between science and language is reversed). The importance of an interdisciplinary approach cannot be overstated with regard to language minority students. It involves them directly in the kinds of purposeful, communicative interactions that promote genuine language use, which arguably are the most productive contexts for language acquisition, such as talking in the context of doing science and trying to solve a meaningful problem. It also creates opportunities for students to use the languages of science and mathematics in ways that schools and the society at large require: not just to read textbooks or do computations, but to write reports, argue a theory, develop evidence, and defend conclusions.

A brief example will help illustrate what we mean. In a Haitian bilingual combined seventh and eighth grade, students explored relationships among truth, belief and evidence in science through an investigation of their school's water. In the Water Taste Test, the students actively tested a widely held belief that the water from the school's third floor fountain was better than that from the other floors. With guidance from their teacher, they formulated their belief as a question and designed an investigation to explore its 'truth'. A blind taste test of about 40 of the school's junior high students revealed that most of them actually preferred water from the first floor although they believed they preferred water from the third floor. This finding prompted the class to pose a new question about the source of the difference and to investigate more deeply the physical and chemical quality of the school's water. Their analysis led them to conclude that temperature was a deciding factor in taste preference, but it also uncovered surprisingly high bacteria levels in the school's water. In the Water Taste Test, and possibly for the first time, the students themselves took control of their learning and, through scientific inquiry, constructed knowledge that was meaningful to them, their teacher, and the larger school community.

This discussion raises the question of the teacher's role in a sense-making culture. Far from backgrounding the teacher's function, a sense-making perspective on classroom practice intensifies it, as Duckworth (1986:133) explains:

> The essential condition of having the students do the explaining is not the withholding of all the teacher's own thoughts. It is, rather, that the teacher not consider herself/himself the final arbiter of what the learner should think, nor the creator of what

that learner does think. The important job for the teacher is to keep trying to find out what sense the students are making.

"Finding out what sense the students are making" of the phenomena they are exploring and, indeed, of their own thinking process entails a significantly different orientation to teaching, learning, and assessment than that found in most science classrooms. Above all, perhaps, it creates uncertainty by advancing a view of knowledge as a human product and a view of classroom discourse as a social process in which argument and conjecture play central roles (Cohen, 1988). This was the case in the Water Taste Test in which the teacher had no idea where the students' investigation would lead, what 'answer' it would produce. Sense-making also entails probing students' talk to find out how they are thinking, the assumptions they are making, the rationale behind their method. It includes helping students think through partial ideas or strategies in ways that do not undercut their own intentions, and involving other students in that process. It also includes valuing alternative interpretations and methods, helping students to explore the implications of their ideas and make connections between their own ways of thinking and scientific ways of knowing (cf. Lampert, 1990). To orchestrate these sense-making interactions, teachers must also have command of the domain knowledge involved in the students' inquiries. For the Water Taste Test, for example, the teacher and students learned about the chemistry of water quality analysis, aquatic ecosystems, hydrology, and water resource management. In a sense-making culture, therefore, "process" and "content" are inextricably linked; teachers guide students in making sense of real phenomena.

Contexts of Assessment in a Sense-Making Community

It may seem odd that in a paper on assessment we have dwelt so long on developing an image of a different kind of classroom scientific practice. But, in fact, this emphasis highlights a crucial point. In the current discussion on the need for accountability (U.S. Department of Education, 1991), there is a danger that we will neglect a critical question: Accountable for what? What is it that we want our children to learn? What does it mean for a student to be scientifically literate? We must not assume that because we are ready to reform assessment we fully understand the thing it is we want to assess better. For this reason, we have chosen to present scientific sense-making as a way to do science in order to anchor our discussion of assessment in a particular context and to emphasize the importance of taking into account the local -- as opposed to the national -- character of assessment.

As outlined in the previous section, scientific sense-making reconfigures teaching and learning in some significant ways. Unlike conventional classrooms, teaching and learning in such a culture are not bound to textbooks, canonical experiments with their correct outcomes, or even a curricular scope and sequence. Students pose questions, design research, use tools to make sense of the world, collect data, build and argue theories, and document and communicate their findings and interpretations in various ways. Students' inquiries stretch over long periods of time, not just weeks but in many cases months. They take unexpected turns. The context of students' scientific work is social rather than individual. Further, in a sense-making culture, teachers take on a variety of roles; they coach and model scientific practices, and they act as co-investigators.

Given this radical change in the classroom culture, in the kinds of processes and products that characterize learning, our concern in this section is to explore some possible contexts of assessment that are congruent with sense-making and that tap the full range of students' learning. In particular, we explore the varieties of learning (Michaels & O'Connor, 1991) that are made manifest through students' talk and writing as they construct scientific meanings. The examples are drawn from classrooms that are working to establish sense-making communities in science. We have chosen examples from a collaboration involving two Kindergartens -- one Haitian bilingual and one English monolingual -- and a multilingual/ multicultural basic skills high school class to show that the kinds of activity and reasoning that emerge in a sense-making culture are as appropriate for five-year-olds as they are for sixteen-year-olds. In the concluding section, we explore how the role of assessment in a sense-making culture can be extended beyond student monitoring to promoting learning and teacher reflection.

Students' Talk: Examples from a Kindergarten Collaboration

Talk is highly valued in a sense-making community as a means for negotiating and constructing scientific meanings. Through talk, students make their thinking public, argue alternative theories, collect data, elicit assumptions, pose questions and conjectures, among other things. Classroom talk falls on a continuum; at one end, it can be organized as a teacher-moderated classroom discussion and at the other it can be spontaneous as in an informal conversation between students analyzing data at a computer. It is, in short, socially situated and multidimensional.

Research has shown that classroom discourse in various domains is enormously complex (Adelman, 1981; Barnes, 1976; Cazden, 1988; Cazden, John & Hymes, 1972; Cook-Gumperz, 1986; Edwards &

Mercer, 1987; Michaels, 1981; Heath; 1983; Wells, 1981). Recent studies have begun to explore the discursive, linguistic, and cognitive characteristics of science and mathematics and the relationship between student learning and the ways in which teachers orchestrate talk (Lampert, 1990; Lemke, 1990; Michaels & Bruce, 1989; Michaels & O'Connor, 1991; Rosebery et al., in press). In at least one case, classroom discussion in science has been explored as a context for assessment of students' thinking (Chittenden, 1990). Taken together, these studies suggest that talk represents a rich, but challenging, context for learning about how students are making sense of the world.

In the following, we explore several examples of classroom talk from a collaborative weather investigation conducted by two Kindergartens, one Haitian Creole bilingual, the other English monolingual. The teachers of these classrooms informally observed and monitored their students' daily use of scientific tools (e.g., thermometers, wind socks, anemometers, rain gauges, bargraphs and charts for representing data) and their talk as a basis for assessing their learning. Our focus is on the varieties of learning that emerge from an analysis of talk.

For the better part of the school year, a Haitian Creole bilingual Kindergarten and a monolingual (English) Kindergarten collaborated on an in-depth investigation of their local weather. Students investigated and collected data on clouds, wind direction and speed, precipitation, and temperature to explore their influence on local weather patterns. They learned to use an anemometer to calculate wind speed, and wind socks and a stationary compass painted onto their school playground to determine wind direction. They observed clouds, noting their color, formation, number, approximate height, and movement; based on these observations, they invented a taxonomy of cloud types. They also learned to use a thermometer to determine air temperature and to check the accuracy of their daily temperature predictions (which became increasingly accurate as the investigation progressed).

Each day, small groups of students collected and recorded data, represented those data in graphs, composed stories of their observations, and the like. They also worked in large groups, reporting their data and observations to one another, and asking and answering each others' questions. Some of their questions included: "What makes the clouds change so quickly?" "Why does the wind sock blow one way and the clouds go another?" "What makes the wind?" "Does it always get colder when it rains?" In the spring, the classes met together on a daily basis to report and discuss their findings and to examine their data (wind speed and direction, temperature, precipitation, cloud cover) for interesting patterns and relationships.

In the following examples of classroom talk, students demonstrate both scientific and mathematical reasoning through tool use and data analysis. The first two examples are taken from a class held in the Spring of 1990 in which three Haitian Kindergartners are reporting the day's weather data to an audience comprised of both bilingual and monolingual Kindergartners and their teachers. In Example 1, Georges, Jonese, and Frantzia are being prompted by their teacher, Christine, to report on wind direction. The exchange takes place in English.

Example 1

Christine: What about the wind? Where was the wind blowing to?
Georges: FROM, Christine!
Christine (smiles and laughs): FROM!...Where was the wind blowing FROM?
Georges, Jonese, Frantzia: From east to north.
Christine: How did we find that out? What did we use for that?
Jonese: The wind socks.
Christine: And where did we stand?
Jonese: In the middle...of the...the compass.

The focus of this exchange is the reporting of the day's wind direction. The most remarkable aspect of the exchange, which lasts under a minute, is the opening two lines when Georges notes aloud that the teacher has misspoken, saying "...to..." instead of "...from..." in talking about wind direction. In correcting Christine, Georges demonstrates that he has not only learned to use the wind sock to determine wind direction but has also learned the standard meteorological convention for reporting it. This standard, incidentally, is not intuitive and is easily confused by adults (as Christine demonstrates). A wind sock, for example, shows very clearly the direction *to* which the wind is blowing; determining the direction *from* which it is blowing requires an inference. Georges's two word counter to Christine makes clear that he has learned how to *talk and think* about wind direction, and that he is not afraid to assert this knowledge. That he insists on maintaining the convention they have established through their own field work is also evidence of the value he places on their work. As we noted earlier, citing Mehan (in press), a discourse community collectively builds up its ways of talking and knowing; it doesn't "make up meanings in any old way." Georges's concern for maintaining the classroom community's standard does not go unnoticed by Christine who laughs good naturedly at his correction and then takes it up in her restatement of the question.

Example 2 takes place a few minutes later in the class. It is an exchange involving both bilingual and mainstream students under the guidance of Christine, the bilingual teacher. Georges, Jonese, and Frantzia have finished reporting their weather data, which included discussion of two different readings obtained for wind speed. In the front of the school they observed that the anemometer made one revolution which calculated to a wind speed of zero miles per hour; in the back of the school (specifically in the teachers' parking lot on top of Christine's car), they observed it make two revolutions which calculated to a wind speed of one mile per hour. At the point we join the conversation, Christine has invited the students to ask questions (a standard practice) and Johnny, a bilingual student, asks Georges why they got two different wind speed readings. Later in the conversation, Susan, a monolingual student, joins in. The exchange takes place in English.

Example 2

Johnny: To Georges, why when you put the anemometer on Christine's car did it turn but not in front?

Christine: That's a good question. Johnny said, "Why when we put the anemometer on the top of the car we had two revolutions and when we had it in front there was only one revolution?" Who can answer that question?

Jonese: Me!

Christine: Jonese? Ok, Georges wants to try it first because it was to Georges.

Georges: (inaud)...

Christine: Ok, Jonese wants to try it.

Jonese: I think that when it was in front it didn't have no wind and when we were in the back and put it on the top of the car it was a little windy and cold and we had two revolutions; first there was one in the front; then there were two.

Christine: WHY is it more windy in the back than in the front? Susan wants to try that.

Susan: Maybe because the building keeps the wind from going around to the front.

Christine: OKAY! Who else has a question. Susan?

Susan: I have a question for you.

Christine: Me!? I hope I can answer it!

Susan: Since it went around two times, does it always go one less miles per hour on the computer?

Christine: Mmmhumm, when it goes around two times, it's one mph, but when it goes around one, it's zero.

In this exchange the students' reasoning is striking. First, Johnny shows that he is thinking critically about the data that have been presented. He articulates what he feels is an inconsistency in the data and demands an explanation. This is exactly the kind of scientific thinking the teachers have been trying to promote in their students throughout the year. The discourse context is not simply

Show and Tell but a forum for making sense of the data the students have generated through their own scientific activity. In this context, then, making sense of an inconsistency in data is standard practice.

Secondly, the explanations that Jonese and Susan generate provide information about each girl's control over the discourse of scientific explanation, at least on this day and in this situation. Their explanations differ in crucial ways. Most significantly, Jonese's response does not meet the (implicit) criterion the teachers have established for scientific explanations. She offers a reason for the difference in wind speed, saying that in front there wasn't any wind while in back there was, but, according to the teachers' standard, it is tautological; it doesn't explain the data so much as repeat them. Christine notes this in her response by rephrasing Johnny's question to emphasize causation ("WHY is it more windy in the back than in the front?"). Susan's response, in contrast, is closer to the teachers' notion of explanation; it contains an explicit marker ("because") and elaborates a plausible reason ("Maybe because the building keeps the wind from going around to the front."). This example raises an important question. While Jonese and Susan respond very differently to the call for an explanation, the talk itself does not help us understand *why*. Is it because Jonese is less familiar with the discourse of explanation in this context? Does she not understand the teacher's question and its implicit discourse assumptions (Michaels & O'Connor, 1991)? Are the criteria for explanations too implicit (Delpit, 1986, 1988)? Regardless, Jonese's difficulty should serve as a signal to her teacher to probe its source more deeply, or in Duckworth's words, "to find out what sense the students are making." We will return to this example in the next section when we discuss the role of assessment in a sense-making culture.

A third and final snapshot of students' learning in this exchange is represented in Susan's question to Christine ("Since it went around two times, does it always go one less miles per hour on the computer?"). This question is noteworthy for what it reflects about the depth and nature of Susan's thinking. On the basis of the data presented in class that morning, Susan poses a question to test a rule for calculating the wind speed in miles per hour based on the number of revolutions of the anemometer (something like: wind speed = number of revolutions – 1). While her algorithm is not correct, it is evidence that she is examining the data for patterns and then using those patterns as the basis for generating rules, a highly sophisticated form of reasoning. At the time of the exchange, neither Christine nor the monolingual teacher understood that Susan was testing a generalization. Prompted by one of the researchers, Christine follows up with Susan the next day (unfortunately their conversation was not recorded). Christine reported afterward that once she understood Susan's intended meaning, they went to the cumulative weather chart the classes had been developing and together examined several days' worth of wind speed data (revolutions and mph). In this way, Susan discovered for herself that her rule was not supported by the data. This has implications for assessment. By asking Susan to join her at the chart to evaluate the rule against the data, Christine is helping Susan to answer her own question and in the process is introducing her to a standard scientific practice for evaluating a rule or conjecture. Moreover, by scaffolding Susan's activity, she is enabling her to accomplish more than she could have done on her own (Palincsar & Brown, 1984). Although Susan's rule was disconfirmed, her impulse to build generalizations based on observed patterns was shaped, extended, and reinforced through the teacher's action.

By way of closing our discussion of students' talk as a context for assessment we will examine an exchange that took place between three boys in the bilingual Kindergarten, Johnny, Pierre, and Josef, in an informal interview situation. The boys are being asked to read and interpret a set of daily temperature graphs (barcharts) their class has developed over several months. The discussion takes place in Haitian Creole and appears below in Haitian Creole followed by English translation.

Example 3

Interviewer: Ki sa ki deye nou la? (They turn.)
Johnny: Yon bagay ki pou weather a.
Josef: Le-l fe cho oubyen fret. Le bagay la ba, se cho l ap fe.
Interviewer: Se vre?
Johnny: No, fret!
Josef: Yeah—Le l wo se
Johnny and Josef: *cho*!
Interviewer: OK, ou ka gade sou premye a, sa ki an le a, ou ka di nou ki jou ki te fe pi cho an janvye? Ki jou ki te fe pi cho?
Johnny: Saa? (Pointing to the highest bar in the middle of the graph.)
Interviewer: Ki nimewo ou we li ba ou?
Johnny: Yon sis avek yon kat.
Interviewer: OK—
Josef: Men ni, men ni men ni! (Pointing to the highest bar at the end of the graph, also with a value of 64.)
Interviewer: Konben li fe, Josef?
Josef: Yon sis avek yon kat.
Pierre: Mwen we *sa* ki cho (pointing to a day when the temperature was zero and another when it was around 30).
Interviewer: Se sa ki pi cho?
Pierre: Yeah.
Johnny: Sa ki pi fret la, se saa (pointing to the lowest bar on the graph).

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Pierre: Pi *cho*, sa ki pi *cho*, sa ki *fret* la (pointing, it seems, randomly at bars on the graph).
Interviewer: Sa ki fe ou di sa? Sa ki fe ou konn se sa ki pi cho?
Scott: Paske li menm ki pi gwo pase saa, pase, sa pi gwo pase...(tracing with his finger up the side of the graph).
Interviewer: Johnny, ou ka ede-l ? Li di se premye a ki fe pi cho, eske se vre?
Johnny: (Shakes head "No".) Saa ki pi cho (pointing to the highest bar at the end).
Pierre: Sa ki gwo pase a (pointing to the highest bar in the middle).
Interviewer: Ou ka explike l poukisa, ou ka di Pierre poukisa?
Johnny: Se paske sa pi wo, li gen pi plis.
Pierre: Sa pa pi gwo (pointing to the highest bar at the end).
Josef: Li gen karant kat.
Pierre: Se paske sa (pointing to the highest bar in the middle) ki pi gwo pase saa (pointing to the highest bar on the end), epi sa pa pi gwo (pointing to the low bar next to the highest one on the end) sa (pointing to the highest bar in the middle) ki pi gwo pase a.
Interviewer: Sa ou panse, Josef? Kiles ki pi cho?
Josef: Saa ki pi wo (pointing to the highest bar at the end).
Interviewer: What's that behind you? (They turn.)
Johnny: A thing for the weather.
Josef: When it's cold or hot. When the thing is low, then it's hot.
Interviewer: Is that true?
Johnny: No, cold!
Josef: Yeah, when it's high it's —
Johnny and Josef: hot!
Interviewer: OK, can you look at the first one, the top one? Can you tell me which is the hottest day in January? Which day is the hottest?
Johnny: This? (Pointing to the highest bar in the middle of the graph).
Interviewer: What number is it?
Johnny: A six and a four.
Interviewer: OK—
Josef: Here it is! Here it is! Here it is! (Pointing to the highest bar at the end of the graph, also with the value of sixty-four.)
Interviewer: How many is it, Josef?
Josef: A six and a four.
Pierre: I see *this* is hot (pointing to a day when the temperature was zero and another when it was around 30).
Interviewer: That's the hottest?
Pierre: Yeah.
Johnny: This is the *coldest* one (pointing to the lowest bar on the graph).
Pierre: *Hotter*, this one's hotter, this one's cold (pointing, it seems, randomly at bars on the graph).

Interviewer: Why do you say that? How do you know it's hotter?
Pierre: Because this is bigger than this, this is bigger than this (tracing with his finger up the side of the graph).
Interviewer: Can you help him, Johnny? He says that the first one's hotter, is that true?
Johnny: (Shakes head "No".) This is the higher one (pointing to the highest bar at the end).
Pierre: This one's higher than it (pointing to the highest bar in the middle).
Interviewer: Can you explain to Pierre why?
Johnny: Because this is the tallest, it has the most.
Pierre: That's not the biggest.
Josef: It's forty-four!
Pierre: It's because this one (pointing to the highest bar in the middle) is bigger than this one (pointing to the highest bar on the end), and this one (pointing to the low bar next to the highest one on the end) isn't big[-ger than] the one bigger than it.
Interviewer: Is that what you think Josef? Which is the hottest?
Josef: This one is the highest (pointing to the highest bar at the end).

While this discussion took place in an informal interview, we observed similar conversations taking place spontaneously as the children examined their graphs and data charts. It is clear from the above discussion that Johnny knows how to read and interpret a bar graph, relate it to the phenomena it represents ("This is the coldest one."), and articulate its meaning to others. Pierre, on the other hand, does not seem to understand the graph and, perhaps most distressing from a teacher's perspective, seems unaware of his own confusion. The state of Joseph's understanding is somewhat less clear from this bit of transcript. At the end, however, when he explains in response to the interviewer's question "Which is the hottest?" that the hottest day is the highest bar suggests that he does understand how the graph represents hot and cold temperatures, and that he can translate between different ways of making sense of the graph.

Our purpose in presenting the above examples is to demonstrate the richness of classroom talk and its relationship to student learning. Through their talk, students showed varieties of sense-making. They mastered the use of specific tools and the concepts underlying their use; they interpreted graphs, critically analyzed numerical data and suggested generalizations based on those data; they built explanations and posed questions focused on data they had generated. In addition, the focus on classroom discourse brought to light instances of talk in which the meaning of that talk was not understood, either by the teacher or the student. These instances underscore the need for explicit discussion of the standards and assumptions for talk in a scientific community (Delpit, 1986; 1988; Michaels & O'Connor, 1991). But this suggestion should not be construed as a call for teaching students the 'rules' of talk or specific forms of explanation or vocabulary. Rather, it means that the classroom community itself needs to reflect on its talk in order to establish its own standards and uncover implicit assumptions. Concern for talk -- how to put forward effective arguments, pose provocative questions, and marshall convincing evidence -- should become an integral part of the work teachers and students see themselves doing, that is, a distinguishing feature of their work as members of a scientific sense-making community (cf. Brown & Campione, in press).

Students' Writing: Examples from a High School Field Ecology Study

Portfolios represent one variation on the theme of alternative assessment in writing, one that also has potential in science. As Wolf, Bixby, Glenn & Gardner (in press) explain, the concept of a portfolio itself has begun to evolve from a structured sampling of a student's work over time to the idea of a process-folio (Gardner, 1989, in press; Wolf, 1990) which differs in several ways from the traditional conception:

> [Process-folios] differ from familiar portfolios in a number of ways. The generation of these process-folios is embedded in a much larger classroom context where teachers and students frequently discuss what goes into creating worthwhile work, what makes for helpful critique, and how to plow comments back into ongoing work. In addition to finished works, these collections contain sample "biographies of work" -- documentation of the various stages of a project. When collected at diverse points, these biographies permit a longitudinal look at a student's changing control of the processes for shaping a final piece. Students often keep journals and write reflections about their work (Seidel & Zessoules, 1990). Finally, the collections of work students build are anything but archival. They regularly return to earlier works to revise or make comparisons with later ones. At the close of the year, students reenter their collections to make a final selection of biographies, reflections, and final pieces that can serve as the basis for a course grade and/or part of a permanent record of their development (Camp, 1990a, 1990b; Howard, 1990; Wolf, 1989). In this sort of work, students have the opportunity to see samples of different levels of work and to discuss the criteria that distinguish strong performances. They also witness the multidimensional nature of such work (i.e., that it involves the ability to pose an interesting problem, to learn from and comment on someone else's work, or to revise an earlier draft.) (Wolf et al., in press:34)

The idea of process-folios strengthens the link among teaching, learning, and assessment by blurring the boundaries which in conventional practice separate them. Process-folios represent an intriguing possibility not only for capturing the complexity and richness of students' scientific sense-making but for making assessment a more integral part of what teachers and students see themselves as doing in the classroom. In a sense-making culture, students' work is not only sustained over long periods of time but is subject to critique, review, false starts, new questions, and a variety of choices that are often contextually contingent. As students conduct investigations, they keep notebooks that contain a wide range of informal "writing" including questions, hypotheses, data tables, graphs, notes about experimental procedures, informal analyses and interpretations of data, and the like. They also produce formal texts such as charts, graphs and reports for publication, i.e., for an outside audience.

In this section, we look at examples of the informal scientific writing of two Haitian students, Rose and Marie. We analyze their texts for evidence of the ways in which they are making sense of data they developed. Both students were in a multilingual basic skills class in a large urban high school. (Six different languages were spoken in the class.) Their class was composed of students who were judged not ready for the regular bilingual program because of low academic skills. For the most part, these students could not read or write their first language or English.

During the school year, the class studied water quality using their home tap water as the basis of study. In the spring, their interests broadened to encompass an ecological study of a local pond that bordered the city's water reservoir. The students were concerned that the pond, which was obviously polluted, posed a threat to the city's drinking water. To address their concern, the students decided to study the health of the pond, including an analysis of its chemical, biological, and physical characteristics, and to investigate the city's water supply, learning about its sources, how it is purified, and how it is piped throughout the city. To complete their investigation, the students broke into small groups to work on particular aspects of the study.

Rose's group, for example, was responsible for determining the bacteria level of the pond. In keeping with their year-long interest in home water, the group decided to compare the bacteria level of the pond to that of their local drinking water. They were interested in two things: How much bacteria was in the pond? How much bacteria was in their drinking water? To answer their questions, they collected water samples from the pond, their homes, and school drinking fountains and tested them.

To perform this test, the students used commercially available culture kits called Millipore™ samplers. These samplers are made of an absorbent, nutrient-filled pad which is marked with a grid. To test for bacteria, the pad is immersed in a water sample, placed inside a plastic container, and incubated under a lamp for twenty-four hours. At the end of twenty-four hours, the grid is inspected for bacteria colonies which appear as tiny black, blue, or green spots. A pamphlet accompanying the samplers allows the user to assign a water quality grade based on the number of colonies that grow. To be drinkable, water must have a count of zero.

For undetermined reasons, many of the students' cultures did not grow. A few did, however, and Rose used them as the basis for investigating the bacteria level in the city's tap water. Her first step was to document her results. She drew a facsimile of the Millipore™ sampler in her lab notebook, reproducing the position and size of each of the 57 bacteria colonies that had grown. Her drawing was a meticulous and accurate reproduction of the culture. She then interpreted the significance of her findings. According to the standards stated in the Millipore™ pamphlet, the tap water, which had come from a student's home, was not fit to drink. Rose documented her findings in her notebook in English as follows:

> I counted the bacteria in the tape water.
> I find fivety seven bacteria in the tape
> water. That's mine you can't not drinking
> but you can swim on that water --
> Grade B for that water because whole body
> contact no more than 200/100 ml.

Rose's report, brief as it is, draws on diverse resources and voices to communicate her finding and its significance. For example, because she is concerned that her report be viewed as credible within her scientific community, she uses two devices common in the discipline to lend her argument validity -- referring to other literature and making her data publicly available. She establishes a connection, if only implicitly, with the standards that accompany the Millipore™ samplers ("That's mine you can't not drinking but you can swim on that water -- Grade B for that water because whole body contact no more than 200/100 ml."). To lend a sense of precision and verifiability to her report, she includes her representation of the sampler and reports the bacteria count in her analysis, in this way documenting her interpretation.

The discourse strategies Rose uses to organize her report also reflect her desire to communicate her scientific activity in accurate detail. She describes how she came to her results and what she found, clearly marking them as the product of her own efforts through use of the first person authorial voice ("I counted..." "I find..."). Not only is she reporting her scientific method but, by using the first person, she marks her result as a personal construction which does not exist apart from her work or reasoning. Note, however, that when she interprets the data according to the standards, Rose switches from the first person to the more authoritative, objective voice signalled in: "That's mine (That means) you can't not drinking but you can swim on that water. Grade B for that water because whole body contact no more than 200/100 ml." Here she is appropriating the words of the Millipore™ pamphlet to interpret her finding and to inform others of its significance: the water used in this sample is fit for whole body contact but not for drinking. (Grade B water, which is suitable for whole body contact such as swimming, can contain a bacterial count of 1-200 colonies per 100 ml of water.) This switch in voice suggests that Rose is aware that scientific results are reported "objectively," apart from the agent who produced them. The presence of both personal and objective statements in her report reflect her struggle to coordinate these voices as part of a coherent whole.

From an assessment perspective, what stands out in Rose's work is the way in which she takes control of the bacteria study, shaping it to her own purposes, taking a point of view, and then interpreting her activity and its significance for a larger community. Rose's activity and her report are evidence that she is beginning to think, act, and write like a scientist. The mixed levels of description and explanation, the orchestration of multiple voices, the recourse to standards and multiple representations reflect her own efforts at sense-making and belie the surface simplicity of her report. These sense-making efforts reflect her struggle to appropriate scientific ways of thinking, knowing, and writing. She is working through for herself the relationship between the processes by which she produced her finding ("I counted..." "I find...") and the means for communicating that finding ("That's mine..."). This effort is a key aspect of scientific practice, one that is well-known to anyone who has struggled to craft a "story" about data. That Rose does this in English, by her own choice, only adds to the complexity of her task. From a sense-making perspective, then, Rose's report, which on the surface seems simplistic and full of errors, is actually a complex text that shows she is beginning to forge a scientific voice.

About the time that Rose was finishing her study, the Basic Skills class was preparing for a field trip to the city's water treatment facility. The trip was set up so that the students would be able to ask questions of the city's water chemist at the end of their tour. In anticipation of this, the students were asked to generate questions they wanted to ask the chemist.

Many students had just finished reading a booklet, "The Story of Water," prepared by the city's Water Department which explains in pictures and words the water cycle and water treatment process. Under the direction of a classroom teacher, many of the students had developed a set of questions based on their reading. A quick survey of students' notebooks showed that approximately two-thirds of them contained the following kinds of questions:

"What machines are used to purify water?"
"What is chlorination?"
"What is filtration?"

From a sense-making perspective, these questions are odd. They are about science content without being linked to authentic inquiry. They seek knowledge that is already known rather than knowledge that needs to be constructed. In short, there is little sense-making to be found in them. They are, however, typical of the kinds of questions students are frequently asked in school where the focus is on factual comprehension and recall.

In contrast, Rose and her partner, Marie, used the bacteria results as the basis for developing a different set of questions that grew directly out of their own scientific activity. The students first composed the questions that follow in Haitian Creole and then translated them into English:

"I went a (sic) know how come bacteria come in the water?"
"How come they clean (sic) the water but it still has bacteria in it?"
"I went to know how often they clean the water?"

It is interesting to explore from an assessment perspective how Rose and Marie's questions differ from those of the rest of the class, and what they tell us about the students' scientific reasoning. As we noted earlier, the questions taken from the Water Department booklet have little to do with the students' own sense-making. "(I)t is as if they put themselves in quotation marks against the will of the speaker" (Bakhtin, 1981:293-94). The lack of student agency and purpose is perhaps most clearly reflected in the impersonal, objective voice in which the questions are cast. There is no sense of ownership, of the students actively asking and answering questions.

Rose and Marie's questions, however, presume an active, critical stance toward the world and, in particular, toward their finding. In a very real sense, their questions represent an action and assert a will to know ("I went to know..."). They literally call into question the dilemma posed by Rose's findings ("How come they clean the water but it still has bacteria in it?") and seek to resolve it. Unlike the class questions, these questions are openly purposeful and evaluative, expressing a particular point of view and designed to produce knowledge. Through their questions, Rose and Marie continue the process of sense-making initiated by Rose. Thus, while at first glance the class questions seem to be scientific in content and tone because they are "objective," they are not. In contrast, Rose and Marie's questions, which are markedly "subjective," are solidly grounded in scientific activity, evidence, and reasoning.

Writing of the kind presented above represents only one aspect of the work students produce in their scientific investigations. In addition, they write notes and make drawings of their observations, tabulate and represent data, design data collection instruments, and draft and finalize reports, among other activities. These texts are sometimes the work of an individual and sometimes the work of a group. They may represent half-baked ideas, rejected plans, or revised thinking. Thus, their role and use in assessing student learning needs to be carefully thought through. In fact, as Wolf et al. (in press: 27-28) suggest, such "assessment is not a matter for outside experts to design, rather it is an episode in which students and teachers might learn, through reflection and debate, about the standards of good work and the rules of evidence."

Roles of Assessment in a Sense-Making Culture

With the emphasis on performance, portfolios, and exhibitions, the assessment reform effort is attempting to blur the edges separating learning, teaching and assessment (Gardner, in press; Hein, 1990; Sizer, 1984; Wolf, 1989). These kinds of alternative assessments acknowledge the situated nature of cognition as they seek to explore student learning in complex, multidimensional activities that are representative of the work of a particular discipline. In some cases, they recognize both students and teachers as active participants in the process who set the standards to be applied to their work (Stock, 1990; Wolf, in press). In this atmosphere of critical reform, it becomes possible to rethink not only the means of assessment but also the roles it can play in teaching and learning. In this section we explore the implications of our prior analysis of student talk and writing for uses of assessment in the science classroom, particularly in promoting student learning and teacher reflection.

In the preceding section, we noted a difference in the kinds of explanations Jonese and Susan put forward for the wind speed data. We also commented that based on the talk itself it was impossible to determine *why* Jonese responded in the way she did. Moments like these represent one of the strongest arguments for linking teaching, learning and assessment as part of a larger enculturation process. It would be easy to judge Jonese as not having a theory to account for the difference in wind speed readings whereas Susan does. But her talk doesn't allow that inference. It is unclear from what she says whether she doesn't have a theory or doesn't understand the discourse assumptions underlying the teacher's question. In moments like these, it becomes the teacher's job to find out the reason and then to build on this knowledge to promote Jonese's learning, to help her gain access to the assumptions and rules that govern discourse in science in that classroom.

Teaching of this kind calls for a level of reflective practice (Schön, 1983, 1991) that is not only rare in schools (largely because it is not valued) but is also likely to be difficult to achieve without considerable effort and dedication of resources. But the benefits far outweigh the costs. To be convinced, we have only to consider the subsequent episode when Christine, after initially misunderstanding Susan -- and, as a result, missing the real import of her question -- returns to it the next day to find out her intended meaning which they then test against the evidence. Not only does the teacher learn something important about the depth of her student's reasoning but, by her action, she also places a high intellectual and psychological value on that reasoning. Taking students' questions seriously, probing their intended meaning, working to understand the assumptions on which they are based represent the kinds of actions that make teaching and assessment part of a larger reflective practice.

Not only do teachers need to become more aware of the complexity of classroom talk, writing, and activity and their relation to higher order thinking and discourse appropriation, as Michaels & O'Connor (1991) suggest, but they also need to develop better articulated views of science as a sense-making practice. These deeper understandings are needed if the effort to develop new forms of assessment is to succeed. For example, the scientific value of Rose's text and Rose and Marie's questions is not transparent. Indeed, it would be easy to be misled by the surface features of the texts (grammar, spelling, brevity) into underrating their scientific merit and the work that went into them. To appreciate the character of their sense-making requires having an insider's view of what it means to do science. This implies that teachers must become sense-makers themselves, as doers of science, teachers, and researchers interested in understanding and amplifying their students' ways of knowing. Indeed, in expert practice, these three roles interact; the ideal is a teacher who embodies and enacts all three as part of his or her classroom practice (Duckworth, 1986; Schön, 1983).

Helping teachers to think more deeply about science and classroom talk does not mean simply teaching teachers about new curricula or new teaching strategies. As a vehicle for change, innovative curricula are not enough; nor is current in-service (or preservice) education. While these may provide teachers with a grounding in the underlying scientific concepts and with hands-on activities to use in the classroom -- and, in the case of some in-service courses, with direct experience using those activities -- they do not touch on the deeper issue on which teacher change depends, namely, teachers' views of science and science pedagogy. The real issue is epistemological change, to bring about a shift in teachers' beliefs about science and pedagogy as well as a shift in their teaching practices toward a sense-making perspective.

Attempts to redraw the face of assessment in science must therefore be grounded in teacher development. The standards of good scientific practice cannot be imposed from outside the teaching community; they must be constructed from within, ideally through active debate not just between teachers and researchers but also between teachers and their students (Wolf et al., in press). In these ways assessment can become an occasion for both improving teaching and amplifying students' learning. Issues like these must be addressed as part of our reconceptualization of science assessment.

The significance of the links connecting teaching, learning, and assessment should not be underestimated. The analyses of student talk and writing we presented earlier represent *our* interpretation of students' scientific thinking based on our own view of what it means to be scientifically literate. The teachers' assessments were more informal, less tied to a view of science as sense-making. They tended to focus more on conventional categories such as students' facility with numbers, growth in language, quantity of talk, although as the year progressed they placed more value on the quality of the students' questions, their understanding of data, their critical-mindedness, and their initiative in defining questions or problems to explore. Their thinking on these issues continues to evolve. This, we believe, is where the hard work of assessment resides, in translating a view of what it means to be scientifically literate into criteria that can capture diverse student performances and varieties of thinking. This translation, moreover, cannot be made for teachers; rather it must be made *by* teachers based on their own elaborated understanding of what it means to be scientifically literate.

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Response to Beth Warren and Ann Rosebery's Presentation

Ron Rohac
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I come to you from about 15 years of the classroom wars. I am still in a classroom, and I have no scars or wounds to show for it at this moment because I've only been in class one day. The school district was nice enough to release me to come to this, and I am very honored to be here.

First of all, I thought I should give you some background as to my experience with limited English proficient students and then go from there in terms of discussing what implications there are with the paper, some of the problems she illustrated and pointed out, and then some methods of assessment that I use in my classroom so that my students will be able to tell or to show me that they understand the science content that I deliver to them, and their application of such science and information.

I have up to as many as 15 different languages in my classroom. I usually have a group of 25 students, at least that's set down by the district, which usually bulges to about 35, and by the time I get back on Monday, I'm sure each class will be about 50. Hopefully by that time, they will have divided the classes in half again and that I will have 25 students. They come to me from a range of backgrounds. Obviously, with different language backgrounds in different parts of the world, they generally come to me with limited English ability and I should tell you what that meant -- at least in my district -- when they asked me to do this kind of program. Like most new teachers to a program I was coerced into starting it. They told me that limited English meant that they did not speak English very well.

I grew up in Canada and taught in Canada for seven years. But when I moved to southern California, I found the students that I faced in a high school setting didn't speak English very well either, so I didn't see the difference at that point. Then they told me that the primary language was not English. So I understood that was the case and that shouldn't have been a problem. So I asked, "Exactly how am I to teach these students." They told me to speak slower, speak louder, and do lots of things. That's sheltered English. After a little bit more training and a lot more experience, we've come to revise that program substantially.

For the San Bernardino City Unified School District, a sheltered program is a content area where the youngsters are taught at grade level and English is not their primary language. I think it's really important that I emphasize that point again, that students are taught at grade level. There is no remediation of the course content whatsoever. My particular courses of study are physical science which are elements of chemistry and physics, and life science which is biology. The students are receiving ninth and tenth grade science credit, and they are working and functioning at that level and are achieving well beyond what most people expected them to do.

The paper, as I see it, raises two important problems for ESL students who are limited--and I don't like the words limited English students to be perfectly honest. The first word, limited, is not something that I appreciate. The first one was that science classes have not traditionally done what they're intended to do. I agree with that entirely, that science classes as they are traditionally taught are the drill and kill effect. That is, you will memorize a bunch of words and you will spit the words back to the teacher and if you do that you get an A, if you do a little bit less you get a B, and so on down the way. That's not the purpose of science education.

Second, for many LEP students, science teachers are not teaching science classes. That's a major issue and concern. It's usually left up to the ESL teacher--assuming science is in the curriculum. An ESL teacher is not a science specialist and my heart goes out to those people that are teaching those classes because they do not have the background experience or knowledge to truly teach science as it is designed to do. In the new framework which Dr. Warren has set out, it would not be possible for a non-science teacher to teach that class effectively. You would in essence be doomed to failure. The purpose of a science class should be to develop a way of solving questions. My particular idea behind teaching science is to instill the question, why, to my students.

Students should leave with an understanding of how to solve a problem but, most importantly, to ask a question why, and then go about their business of solving that particular question, or series of questions, to come up with answers that I'm going to pose to them. I agree with the idea that students should emphasize their particular opinions and their interests, but I am also a great believer in the formation of a curriculum that they must follow and, with proper teaching techniques, styles, and methodologies, the teachers can direct their students through elements of science and extend this particular methodology to the students' interest.

About 16 years ago when I graduated from college there was a wonderful new element of science education that was being purported and that was called the discovery method. A few years ago I read another article that talked about into, through, and beyond. I'm looking at another one called sense-making problems, or problem solving as sense-making ideas. And my question to the people involved in those things a few years ago or 16 years ago is this: If I have a 20-chapter curriculum to follow and I use only the discovery method to teach, then my youngsters will get to the end of Chapter One. They will not achieve the curriculum, and they will not be able to formulate the ideas and things set out by me, the district, and the state. I think there are some important issues to deal with, and science must be attested on these different levels.

Concerning the first business with the teacher, I wanted to talk a little bit about what ESL teachers are doing. I saw it as being a compliance issue or, should I say, an out of compliance issue? If ESL teachers are teaching science, then this particular district is not in compliance with the state recommendations. Science teachers are supposed to teach those courses. If I am to teach a math class, then the district will most likely slap my hands and get me back to science courses or social studies. Therefore, why are we expecting ESL teachers to teach a class that is very complicated and complex and definitely has all sorts of wonderful ramifications and they're just trying to struggle with the language. That's a whole game to themselves.

But the purpose behind what I'm supposed to do here today is talk about assessment and so I have some other things to deal with. A sheltered teacher will be given specialized techniques so that students can achieve the content. That is, they will provide comprehensible input. Listening to other things this morning, we seemed to have gotten away from the idea of something called, BIC's and CALP. Maybe that's very small potatoes in terms of this particular symposium but, as I understood it, my youngsters came to me with a basic understanding of English, or very minimal understanding, and the things that I'm going to teach them, the cognitive things, are the things that they're supposed to comprehend. my focus is basically on that particular level.

The techniques that I work with to gain this comprehensible input can be summarize into four major points:

One, we use things to visualize concepts, picture files, whatever it takes in essence to make an abstract concept concrete. That's what I'm really most interested in.

The second business of teaching is the development of hands-on activities and materials so that youngsters can go beyond what they see and understand and extend that particular concept to the application level. I am very concerned about Bloom's taxonomy in that youngsters will get into applications synthesis and evaluative components based upon things they have to do and construct. Cooperative learning, to take advantage of students' strengths and build on their weaknesses and to take advantage of the diverse backgrounds with which my students come to me. If we have 15 or 16 different languages in the classroom, we literally have a world of experiences, and their perspectives are different. And, if given the current situation, these different perspectives can be powerful tools for science education.

Then something else called guarded vocabulary, the method by which the teacher speaks, our rate of speech, our ability to enunciate words, to avoid idioms and colloquialisms, to use things in context efficiently, will allow my students to gain something called comprehensible input. In essence, my students will understand what it is I'm trying to present to them, they will be able to use that information and prove to me that they understand the concepts presented. The techniques described present a pragmatic methodology to teaching. Their goals are similar to the goals of the directions to developing scientific literacy. When I think of what goes on in the state of California now with the new science frameworks and the sheltered techniques that we use in the classroom, there are mirror images: one, to make content meaningful; two, to emphasize concepts rather than teaching fragmented bits and pieces of science; three, to develop and utilize skills taught to develop a creative and critical thinking level; and four, to teach vocabulary as needed to function in and around the concepts.

I will not teach words just for the sake of words; they have to have meaning behind them. As can be seen, the sheltered classroom focuses primarily in content. It is because of this focus that language can be acquired because language will have meaning. That's a key ingredient for me -- language will have meaning. It has been my experience that students develop science concepts and English without compromising the content.

Techniques used to assess students should reflect a teaching style used by the teacher. In this case, we must look for pragmatic ways to assess performance. Authentic assessment techniques allow students to demonstrate their knowledge. I have nine listed here and I would just like to go through them briefly.

One technique that I use is open-ended questions and open-ended activities. In open-ended questions, what I'm really most concerned about is that the students are going to tell me how they think they are processing their learning. That sounds like a lot of words but that's really the case. In open-ended activities, the student will demonstrate application. A nice example of an open-ended activity for my students is to hand my pairs of students pieces of aluminum foil. Their job is to tell me how thick it is. They have been worked through the areas of metric system in measurement, they have been worked through the areas of density, and they have all of these wonderful tools available because they've gone through that process and they've done all the measurement things. But it isn't enough. They have to be able to apply that information. So when I hand youngsters a piece of aluminum foil and ask them how thick it is, then they must be able to use that information. There are several possibilities that could be the correct answer depending on how the youngster thinks, in essence, his perspective and background, then it will be his solution. None of them can be wrong.

Another technique is the use of performance based tests which represent nearly 50 percent of my grading scale. Here, the youngster will show me what he/she knows, designing a human face based upon genetics information, building all sorts of different structures such as designing a cell, the components of a cell, are good examples of performance based activities.

So science can be tied to other curricula -- social studies, reading, writing, all are important. So they do not see science as being something else, we can't do this in class today because that's math and this is science class. What I usually tell my students at that point is, well, we shouldn't open the textbook today because we would be reading and that's English class.

Enhance multiple-choice questions. Here, an enhanced multiple-choice question represents the only kind of multiple-choice questions my students will see. Those particular questions, as such, being enhanced, use some form of the visual that is completely tied to the question. In other words, the question could not be answered without the presence of visual forms. Multiple-choice questions for the most part for my students are multiple guess. I am not testing their ability to read English, I am testing their science ability. So I try to avoid those.

Another technique which has gained lots of popularity in all sorts of subjects is the use of student portfolios. But there are teacher components which we call the evaluative component and student components which are the effective components. Students are responsible for inputting information into their portfolios. After all. they are their portfolios.

In this regard, I want to mention the use of interactive journals to practice writing. In a non-threatening way, students are going to be encouraged to write. The process the students are actually formulating, and the answer, is to define what science is. That's one of their jobs while I am gone for three days. They have been assigned to groups and they're to come up with a definition of what science is and that includes what will be included in this course, what they expect. Many of my students have never been in a science class. So it is with interest that I go back Monday to find out what they have written down.

Cooperative projects put kids in groups that will take them beyond their individual capabilities. And, by carefully designing those cooperative groups, students have become functional on a number of levels. But it is an exciting process to watch them go beyond the content as I expect to see it.

Finally, I recommend the use of anecdotal notes; things that I write down in class about "student talk." Dr. Warren had talked about student talk as being an important issue, and it is very important because: one, it develops concepts cooperatively; two, students think through problems; three, students express concerns and opinions; and four, students develop language skills. But there's a problem. In my particular classroom, English is not necessarily the language that the students discuss their work in; that's a major issue. If this is truly going to be a sheltered classroom, then the youngsters can function in whatever language suits them the best. As a teacher, I must be comfortable with the fact that they are working. It's been my experience that when students laugh and giggle in my physics class, I know it's not physics.

Student talk is important to the development of concepts, but a question to consider: Is language of the discussion important? I think not. I want my youngsters to struggle with the concepts of science; I do not want them to struggle with the concepts of English. So when they work in Vietnamese or Chinese or Spanish or Hungarian or whatever language, I face that particular day, or that year, it is of no interest to me. The students are functioning and working at their appropriate levels, and they go well beyond what they are capable of in English.

My conclusion, science or any other content-based class can be a powerful language acquisition device for potentially English proficient students. At the same time, it provides an opportunity for students to continue their education at grade level provided teachers do not remediate their courses but rather restructure their approach to teaching and assessment. Secondly, teachers, counselors, and administrators must remove the mind-set of remediating students listed as LEP. Finally, content-based classes should be taught by content-area educators and not ESL teachers. If these criteria are met, there are no limits for limited English students.

Response to Beth Warren and Ann Rosebery's Presentation

Sau-Lim Tsang
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I am going to use a common sense approach in my short talk here.

First of all, I want to comment that the lecture format of this presentation is non-sense making. I am very interested in the "sense-making approach" (I am not sure "approach" is the correct word to use) described by Dr. Warren because it addresses one of the most important objectives of science education. That is, we want our children to be creative, to be critical, to be curious about nature, and to conduct scientific inquiries.

I'm especially interested in the title "sense-making." Actually, when I first heard this title last week, I asked a colleague whether he had ever heard of the term before. He said, "Yes, this is the latest thing, everyone is talking about it." I'm interested in it because science, when defined generally, is the understanding of nature. If you review the history of science, you find that the understanding of nature has always been guided by our perception and our sense.

In the early days, we made observations of the sky and we deduced that the appearance of the comet would be followed by an earthquake. In the Chinese folklore, the appearance of a bright star in the sky meant that a saint or an important person would be born. We drew relationship and conclusions by observing nature closely.

As our perception expanded (for example, when we invented the telescope), we were able to understand more natural phenomena. For example, we began to understand that the earth is revolving around the sun instead of the other way around. And when we invented the microscope and expanded our perception of small things, we also gained more understanding of the working of microscopic matters. Thus, the study of nature is guided by our perceptions, and sense-making is a very important part of science education.

I do have several questions about this sense-making approach. First, I am not clear about the difference between this and "scientific inquiry"; I do not have a clear definition from the paper. How is sense-making different from discovery learning and other similar teaching/learning methods? What happened to all of the science curriculum we developed during the 1960s, a period known as the golden age of science education, when the Congress provided large amounts of money for science curriculum reform and teacher training? One emphasis of the curriculum reform efforts of the 1960s was on discovery learning. Is there any relationship between this sense-making approach and the discovery learning emphasis of the 60s? Maybe Dr. Warren can address this concern in her paper.

Second, I want to know if there are any evaluations being conducted on the sense-making approach. Do we know if this approach is better than other approaches? We should know more about its effectiveness before the practice is disseminated.

Third, I am often confused by descriptions of innovative programs because they are often conducted by excellent teachers. I've been hearing a lot of descriptions about good practices based on one or two teachers. Are we talking about good practices or good teachers? Or is it a tautology? If I select a good teacher somewhere and I put a label on the approach she/he uses, does the approach then become an exemplary practice instantly based on its success with the teacher? I don't know why Jaime Escalante hasn't marketed his teaching method yet, since everyone knows how successful he is with his studies.

Fourth, I also want to know how the sense-making approach relates to children's stages of cognitive development, such as those proposed by Piaget to learning taxonomies, such as the one proffered by Bloom, and by extension, to the objectives for science education at different grade levels. In California, the State Curriculum Framework has developed a set of objectives for science education divided by grade level. For example, from K to third grade, the objective is to help students observe, communicate, compare, and organize objectives in nature; from third to sixth grade, students should understand the interaction and interdependence of systems of objects; from sixth to nine grade, they should explain phenomena through perceived changes in objects; then, from ninth to twelfth, they should use information to obtain further knowledge. How does the sense-making approach relate to these different objectives?

Fifth, I would like to find out how the sense-making approach facilities the ability of LEP students to overcome the language barrier. The paper provided descriptions of the language difficulties encountered by the LEP students and how these difficulties affected their access to the science content. But there was no discussion on how the sense-making approach helps alleviate these problems. For example, the author gave a description of a class project in which the students conducted a tasting test of water samples from different parts of the school building. Were the students who were less fluent in English left out of this project? Did they engage in discussion just as much as the others? I want to see the relationship between the sense-making approach and the education of language minority students.

The last questions I have is whether the sense-making approach can be disseminated to other teachers. If the approach is indeed successful, how are we going to disseminate this method? As was mentioned by the previous discussant, the sense-making approach is highly dependent on the teacher's scientific literacy and knowledge. A recent survey I read said that over 95 percent of teachers today are completely dependent on the science textbook to teach. They do not diverge from the textbook because they have very limited scientific knowledge. How can a teacher with limited scientific literacy adapt the sense-making approach?

I can give you an example. I once observed a sheltered English teacher giving a junior high school science lesson. The teacher was known to be an excellent instructor and well versed in the sheltered instruction approach. She was teaching a lesson on the effect of heat on matter. She was following the textbook and discussing the working principle of the thermometer-that mercury expanded as the temperature increased, thus raising the mercury column in the thermometer. Then a student asked a question: "Oh, yeah, we have a pot at home and the lid is always stuck. We can't open it. But if I put it in the oven, when it heats up, I can open the lid easily." The teacher said: "Yes, that is expansion." But another student asked: "The lid expanded but the pot also expanded. How come it is easier when both are expanded?" This was an excellent question which could be used as a lead-in to many hypotheses, experiments, and scientific concepts. However, the teacher ignored the question (probably because she did not have the scientific knowledge to respond to the question) and went on with the text.

These are all the comments I have regarding Dr. Warren's paper. For the remainder of the time, I am going to put forward some of my thoughts on the current "crisis" in science education.

Actually, this is the second crisis. We had the first crisis in 1957 when the Soviet Union launched Sputnik. We felt that we were losing the battle to the Russians and the federal government implemented a massive effort to improve math and science education. Numerous teacher training programs, curriculum development projects, and research projects were initiated and supported for over a decade. There were also many evaluations conducted with the curricula developed during this era. In general, the evaluations were based on these curricula. Students did as well as students in traditional curricula in factual learning and better in comprehension and concept application. I guess the culmination of all these activities was the moon landing in 1968. However, I am not sure whether putting our first man on the moon had much to do with the massive science education improvement program of the 60s. Instead, the fast advance of scientific research and development capability of this period may well have been the result of the large number of foreign scientists coming to our country.

The current crisis in science education, however, is quite different from the previous one. We are talking about how our industry is losing its competitiveness to other countries, about the fact that we need to modernize our industry and that our work force is not adequately literate in math and science to meet the needs of the changing industry. The last time, we wanted more scientists; this time we are talking about the general public, the general work force. We want them to be more scientifically literate. To ensure that our future work force possesses the required math and science literacy, we need to improve our math and science education.

This line of reasoning, though plausible, might not hold up when we compare it to schooling in Japan, purportedly our most fearsome competitor. The math and science curricula in Japan resemble what we had 40 years ago in the United States. Their work force is perfectly fine for their industry. Why do we have to change our math and science curriculum? That's something we have to think about.

I also want to give an anecdote about science in general. Last year I visited the Lawrence Berkeley Lab (LBL), where they have a special summer program to encourage young adults to enter science careers. In the summer program, they brought together the cream-of-the-crop students who showed interest in math and science related careers from all over the country, to introduce them to many exciting scientific projects that scientists were conducting at LBL.

I observed three young women working on a molecular experiment. One white, one an Indian from India, and one Hispanic. They all showed great enthusiasm and worked diligently at the experiment. Afterward, I asked each of them if the summer program experience helped them to select a science-related profession. The student from India said yes, she enjoyed science. The Hispanic woman said yes, she wanted to become a scientist. By the way, these two women are immigrants to the United States. The white woman, on the other hand, said that the summer program helped her to decide that science was not for her; she thought she would rather be a lawyer because science was just too tedious and boring.

This visit had me thinking about the lack of role models for our youths. When you look at TV today, there's not a single role model who is a scientist. Today's youths are greatly influenced by the mass media. When they look at TV, they see role models of lawyers, policemen/women, and some doctors (e.g. the Cosby show). But there are no scientists (though we do have Dr. Spock in Star Trek, who is not human.) How can we encourage our young people to be scientists?

I want to end with two examples. First, I did a research study six years ago with a group of high school students in San Francisco who are Chinese immigrants. One student especially impressed me. He came to the United States two years earlier from China and was a tenth grader enrolled in an Algebra II class. I asked him why he was taking the advanced math series. He told me that he really wanted to be a writer and his love was literature. However, his counselor told him that he had no chance in this country to be a writer and that he should study math and science to ensure a job in the future.

The second example is about one of my colleagues, who is here at this symposium, a Hispanic woman who grew up in the barrio. She told me that she grew up wanting to be a medical doctor. However, throughout high school, she was placed in a vocational track because she was told that she was not college material. Of course she was not able to study medicine. My colleague ended up a Ph.D from Stanford and she is one of the most capable people I know.

The first example may answer a question I often encounter-that is, why are there so many Asian-Americans in math and science-related professions? Even more disturbing, I am still unsure how I would advise this student if I were his counselor.

The second example illustrates the low expectations school staff hold for Hispanic students. The incident happened in the 1960s, but my current experience with schools suggests that a large segment of our school personnel still has very low expectations for certain groups of our children, and these expectations are often based on generalization without consideration of an individual student's background, ability, and potential.