DOCUMENT RESUME

ED 326 060 FL 018 978

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TITLE	Cheche Konnen: Science and Literacy in Language Minority Classrooms.
INSTITUTION	Bolt, Beranek and Newman, Inc., Cambridge, Mass.
SPONS AGENCY	Office of Bilingual Education and Minority Languages Affairs (ED), Washington, DC.
PUB DATE	Dec 89
CONTRACT	300-87-0131
NOTE	75p.; Appended tables present various legibility problems. For related documents, see FL 018 976-977.
PUB TYPE	Reports - Evaluative/Feasibility (142)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Attitude Change; Basic Skills; Bilingual Educatio: ; *Classroom Communication; *Classroom Environment; Educational Strategies; *English (Second Language); Grade 7; Grade 8; Haitians; Inquiry; *Literacy Education; *Science Education; *Scientific Attitudes; Secondary Education
IDENTIFIERS	*Cheche Konnen

ABSTRACT

A study examined the relationship between science learning and literacy development in two language minority classrooms: a self-contained, combined grade 7-8 class of Haitian students and a multilingual basic skills class within a large high school bilingual education program. In particular, the investigation analyzed the ways in which a model of scientific inquiry was interpreted in the classrooms and the effects of those interpretations on both science and literacy practices. The investigation focused on how the model and the teachers' goals interacted to produce, even within the same classroom, different interpretations of science, which in turn influenced the forms and functions of literacy in the classroom. In both classrooms, the model effectively transformed the kinds of science and literacy practiced from traditional worksheet-based exercises to authentic, communicative, sense-making practices through very different processes. The two case studies are based on the first year of a multiyear project, Cheche Konnen (meaning "search for knowledge in Haitian Creole"), in which researchers and teachers are collaborating to develop an investigation-based approach to science for language minority students. Sources of data include classroom observation, audio- and videotapes of classroom activity, teacher-researcher meeting notes, teacher interviews, and teacher- and student-produced texts. A 45-item bibliography and program materials are appended. (MSE)

Cheche Konnen: Science and Literacy in Language Minority Classrooms

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December 1989

Running head: CHECHE KONNEN

Abstract

In this paper we explore the relationship between learning science and developing literacy in language minority classrooms. In particular, we analyze the ways in which a model of scientific inquiry was interpreted in two language minority classrooms and the effects of these interpretations on both science and literacy practices in those classrooms. The analysis focuses on how the model and the teachers' goals interacted to produce, even within the same classroom, different interpretations of science which in turn influenced the forms and functions of literacy in the classroom.

In both classrooms the model effectively transformed the kinds of science and literacy that were practiced from traditional worksheet-based practices to authentic, communicative, sense-making practices but through vastly different processes. Through two case studies, one of a combined seventh-eighth grade class of Haitian students, and the other a multilingual, multicultural and multiage basic skills high school class, we document and analyze those processes of classroom change, focusing in particular on understanding the ways in which a model for innovation in classroom practices interacts with the larger social system of a classroom (especially teacher beliefs, values, assumptions and practices) to change both the model and the classroom culture.

The case studies are based on the first year of a multiyear project, Cheche Konnen (meaning "Search for Knowledge" in Haitian Creole), in which researchers and teachers are collaborating to develop an investigation-based approach to science for language minority students. Components of the project include teacher education, curriculum development, participant observation, and evaluation. The case studies integrate several different sources of data (classroom observations including field notes, audio- and videotapes of classroom activity, meeting notes from teacher-researcher meetings, interviews with teachers, and teacher and student produced texts) and draw on analytic constructs from anthropology, cognitive science, sociolinguistics and literary theory.

Cheche Konnen: Science and Literacy in Language Minority Classrooms

We know from the seemingly endless barrage of reports that our schools are doing a poor job of producing students who are scientifically and mathematically literate (McKnight, et al., 1987; Mullis & Jenkins, 1988). But if our schools are generally doing poorly in this regard, they are failing language minority students even more dramatically (Mullis & Jenkins, 1988; Steen, 1987).

There seems to be general agreement that the way in which our schools teach science is a large part of the general problem (AAAS, 1989). As the NAEP data show, school science often is an amalgam of lecture, demonstration, memorization and assessment (Mullis & Jenkins, 1988). Students do not typically engage in any direct or purposeful way the phenomena they are expected to understand. They may master some of the so-called "facts" of science but they learn very little about the nature of the scientific enterprise as it is practiced by professional scientists.

For language minority students, conventional school science is even more problematic. Science instruction, when it is given at all, typically takes the most limited, traditional forms. Often it is subordinated to the pressing and legitimate need to develop the students' English language abilities; students memorize the definition of the word "hypothesis" but never experience what it means to formulate or evaluate one. As a result very little science is actually learned. Perhaps more importantly, this kind of learning may inculcate negative attitudes and conceptions about science, especially in language minority students, many of whom come to school without a strong sense of what science in the world outside of school is all about.

The problem for language minority students is compounded in several other ways. First, language minority students tend to live in low income urban school districts with limited resources as measured by per pupil expenditures, teacher:student ratios, and availability of materials and technologies (Office of Technology Assessment, 1987). Secondly, the problem of teacher preparation is no less acute in bilingual education than in mainstream education, and may even be worse. For example, teachers assigned to districts that serve language minority students are often those who are new and uncertified (Reeves, 1988). In addition, very few bilingual teachers have the background to teach science. In 1985, for example, Hispanics earned only 3.3 percent of the total number of bachelor's degrees handed out in the biological and life sciences (Melendez, 1989). Exacerbating this problem is the paucity of useable materials, especially texts, for teaching science in language minority classrooms. Thirdly, attitudes about what language minority students can do and should be doing in school, as embodied in current curricula and teaching practices, often place limits on what they can achieve. Finally, there are the problems that arise from cultural differences (Au, 1980; Heath, 1983; Philips, 1974). Often language minority students' community or home-based literacies (e.g., their ways of talking, thinking, valuing and interacting) do not fit or come into conflict in their underlying values and assumptions with the school-based literacies they are expected to acquire (e.g., ways of reading, writing, talking and interacting with teachers and peers).

To address these concerns, we, in collaboration with bilingual teachers, have undertaken a project called Cheche Konnen, which is Haitian Creole meaning "search for knowledge." The fundamental idea behind the Cheche Konnen investigation-based approach is to involve language minority students, most of whom have never studied science before and some of whom have had very little schooling of any kind, in "doing science" in the way that practicing scientists do. What this means in practice is that students are encouraged to pose their <u>own</u> questions, plan and implement research to explore these questions, analyze and interpret the data they collect, and draw conclusions or make decisions based on their research. The goal of the project is to begin moving the students along a path towards scientific literacy, which we conceptualize not simply as the acquisition of specific facts and procedures or as the refinement of a mental model but as a culturally and socially produced way of thinking and knowing that evolves gradually through engagement in authentic scientific activity.

From this initial characterization of the project, it should be clear that we are attempting an innovation that is very far from the kinds of science learning typically found in the schools in which lectures predominate over investigations and textbook-based learning of facts and procedures predominates over posing questions and interpreting data. In contrast, an investigation-based approach of the kind we are developing emphasizes not only the reasoning processes and conceptual knowledge that fuel the activities of science and mathematics (mathematics here being viewed as an integral part of scientific activity) but also the social and linguistic processes that mediate them. As in real scientific activity language plays a crucial role in the model -- as a system both for thinking and talking about science, and for communicating and sharing ideas.

In this paper we will analyze the first year of implementation of the model. The questions we will explore are: How was the model interpreted in the two classroom contexts in which we worked? What forces helped shape these interpretations? What were the effects of these interpretations on classroom teaching and learning? And, finally, what are the implications of these interpretations for the Cheche Konnen model, both theoretically and practically?

Our analysis will focus on the relationship between the Cheche Konnen model and the contexts in which it was realized. We are assuming that the relationship is, in Mehan's (1978) phrase, "mutually constitutive," that is, the effects go both ways: the context transforms the model and the model transforms the context. We will mostly restrict our analysis of contextual influences to the teachers' goals, although we recognize that not only are larger contextual forces at play but that they also condition teachers' goals, sometimes in very subtle ways. In this paper, we will try to show how the model and teachers' goals interacted to produce, even within the same classroom, different interpretations of science. We will explore the ways in which these different interpretations not only influenced the teaching and learning of science but also literacy, more generally. Our goal is to delineate a model that can help create opportunities for scientific inquiry as well as for purposeful literacy that might not otherwise exist in the bilingual classroom.

The plan of the paper is as follows. First, we will outline the Cheche Konnen model, elaborating not only its basis in research and theory but also some of the ways in which it contrasts with existing practice. Next, we will analyze the model in practice. We will briefly describe key aspects of its implementation, describing the research sites and summarizing the ways in which we worked with teachers and the materials we developed. The heart of this section will be a contrastive analysis of two case studies, one from each of the two classrooms in which we worked. In the last section we will discuss the implications of our findings for the model and for teaching and learning in language minority classrooms.

The Model

> 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 criticise 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, 1987, p. 111)

We begin with this quote from Sir Peter Medawar, the eminent thinker and scientist, because it directly challenges some of the typical school beliefs about what it means to be scientifically literate. First, it challenges the belief that science, at bottom, is the accumulation of knowledge or facts about the natural world. Secondly, it challenges the belief that scientists work according to a rigorously defined, logical method, known popularly as *the* scientific method. And thirdly, it challenges the belief that scientific discourse is represented uniquely by forms of writing and talk that are thoroughly objective and impersonal.

Is it an oversimplification to say that facts are at the base of what is typically taught in the schools? Perhaps, but the evidence is hard to ignore. As reported in the recent NAEP Report, "The Science Report Card" (Mullis & Jenkins, 1988), the few gains that students have made in recent years are due largely to their increased knowledge *about* science rather than to their skills in scientific reasoning. NAEP also collected data on students' experiences with science and found that "both the content and structure of our school science curricula are generally incongruent with the ideals of the scientific enterprise" (p. 17). Schools, in short, emphasize textbook reading and recitation, lecture and demonstration, on arriving at the correct answers that our culture has taught us are correct.

With regard to the methods of science, we tend to confuse the final product of scientific activity, the journal paper with its clearly delineated steps and carefully argued logic, with the process that produced it. One result is that we teach *the* method of science as if it represented the way in which scientists actually go about their work. The result is a distorted view of the role of both reason and imagination in science (Kuhn, 1967; Medawar, 1987). That we are as a culture largely ignorant about what scientists actually do in the day to day practice of their discipline is not all that surprising, for we do not often see behind the curtain of the scientific enterprise. In contrast, the recent debate over cold fusion has provided a rare glimpse behind that curtain, revealing some of the social and intellectual norms, assumptions, values and criteria that govern the conduct of science in our society.

Finally, Medawar's use of the term "story" to describe the purpose of scientific enquiry is instructive. With that one word, Medawar calls our attention to the human, meaning-making character of science. The scientific enterprise is as much mediated by human actions (i.e., what scientists do, how and why they do it) as by language and culture (i.e., how scientists talk or otherwise express their understanding, and the cultural and ideological frameworks -- or theories -- within which the "facts" of science are interpreted). This differs from the notion of meaning that typifies school science and even the larger culture's understanding of science, in which there exists a body of knowledge, apparently beyond the individual's control, that is to be learned and that is conveyed through a largely objective discourse of explanation and fact (Lemke, 1982). Meanings are given, they are explained, and occasionally they are absorbed. They are not constructed through active theorizing (i.e., storytelling[1]), experimentation and observation as they are in authentic scientific activity. One consequence is that the knowledge that results from conventional school science often is inert, bound to the contexts in which it was learned, precisely because it is knowledge whose sense is *given* to the learner rather than *made* by the learner (Collins, Brown & Newman, 1989; Duckworth, 1986).

The Cheche Konnen model attempts to bridge the gap between learning science and doing science by placing investigations at the heart of science education. Moreover, in its essential features, it also seeks to build on what is known about the special resources and difficulties of language minority students. The choice of an investigation-based model is motivated by several lines of related research from a variety of traditions, including educational anthropology, sociolinguistics, cognitive science, cross cultural psychology, science and mathematics education, and reading and writing (Brown, Collins & Duguid, 1989; Collins, Brown & Newman, 1989; Duckworth, 1986; Heath, 1983; Inagaki & Hatano, 1983; Philips, 1972). Taken together, the research argues for a model of science education that emphasizes (1) inquiry, (2) collaboration, and (3) interdisciplinary learning. We briefly discuss each element.

What is an investigation? It is a form of collaborative inquiry that cuts across disciplinary boundaries. More specifically, what we mean by an investigation is that students formulate and carry out a project to answer a question that they themselves have posed about some aspect of the world in which they live. Thus, in collaborative inquiry, it is the students who define the problem to be studied, not the teacher or the text. This is at the heart of what it means to do science. Ideally, every step in an investigation should depend on asking a question. For example, suppose you were investigating the question: How safe is the water in my community? Like most real world problems, this problem is ill-defined. Therefore, you would first need to define it more precisely: Safe for what? Then you would need to figure out <u>how</u> to study the question: what tools and techniques to use, where to take your water samples from, how often to sample, etc. As you move into data collection and analysis, you would need to determine how to analyze your data, how to interpret your findings, and how to represent your data: What is your purpose in doing the study, to whom are you trying to communicate? By pursuing questions they have posed, students will be working toward goals that are meaningful to them and possibly also to their communities (which can encompass the classroom, the school, or the larger community), and they can begin through their own activity to bridge the gap that often separates the school culture from the culture of the home or community (Heath, 1983).

Through inquiry, students' learning is contextualized in the kinds of problems, practical tasks and activities that organize authentic scientific activity. The important pedagogical idea here is that these problems, tasks and activities -- and the social interactions they engender -- support and structure students' learning in ways that enable them to internalize the practices and understandings that underlie the work of scientists (Collins, Brown & Newman, 1989). By planning and implementing investigations, students learn early on to confront the kinds of ill-defined problems that arise out of authentic scientific activity; they learn that there are alternative investigative paths and many different questions that can be pursued at any given point, and, importantly, that there is not necessarily one solution or answer to a given problem.

The second important feature of an investigation is that it is collaborative in nature, just as most professional scientific activity is. 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. Cognitively, 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, 1977; Brown & Palincsar, in press; Hatano, 1981; Inagaki & Hatano, 1983).

Collaborative inquiry also supports important sociocultural values. Chief among these is the demonstrated preference of some minority culture students for activities based on collective rather than individual performance. Several studies have shown that students from a variety of minority cultures are more likely to participate actively in school when they can choose when and how to participate and where group leadership evolves naturally from those choices (Au, 1980; Au & Jordan, 1981; Cazden, John & Hymes, 1972; Mohatt & Erickson, 1980; Moll, Estrada, Diaz & Lopes, 1980; Philips, 1972, 1974).

Finally, investigations are interdisciplinary; science, mathematics and language (talk, reading, and writing) are intimately linked. Mathematics and language are recognized as essential tools of scientific inquiry, 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. The importance of a multidisciplinary 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, but to write reports, argue a theory, develop evidence, and collaboratively solve problems. Additionally, it introduces them to computers as tools that enhance one's intellectual explorations rather than as drill masters that set limits on what one can know.

In summary, an investigation-based approach seeks to forge a link between learning science and doing science, and between doing science and literacy. This is in large part what makes it a powerful model for language minority students. The heart of the approach is for students to formulate questions about phenomena that interest them, build and criticize theories, collect data, evaluate hypotheses through experimentation, observation, measurement and simulation, interpret data, and communicate their findings. Literacy in the form of purposeful talk, reading and writing mediates each of these intellectual efforts.

The Model in Practice

In this section we first briefly describe the two research sites and the implementation process. We then analyze in the form of two case studies the ways in which the classroom contexts (here identified with the teachers' goals for what their students needed to learn) and Cheche Konnen model interacted to produce different interpretations of science and literacy, even within the same classroom.

Research Classrooms

The Cheche Konnen model was pilot-tested in two distinctly different contexts of bilingual education within an urban public school system in Massachusetts. One was a self-contained, combined classroom of seventh and eighth graders in a K-8 school. The other was a basic skills program within the general bilingual program in a large high school. These settings represent in microcosm many of the variations that can occur in the ages, skill levels, interests, and cultural and linguistic backgrounds of language minority students in an urban school system.

The city is a multiethnic community that has offered bilingual education since 1970. Currently, the city's public schools serve approximately 8,000 students, 1000 of whom receive bilingual education. A somewhat higher percentage of the students in the system do not speak English at home. The city's bilingual population is diverse. To address this diversity, the school system offers bilingual education in eight languages at the elementary-middle school level (Portuguese, Spanish, Haitian Creole, Chinese, Korean, Hindi, Gujarati, and Vietnamese) and in four languages at the high school (Portuguese, Spanish, Chinese and French/Haitian Creole).

Seventh-eighth grade classroom. At the K-8 school, which houses the city's Haitian Creole bilingual program and a mainstream program, we worked with a combined seventh-eighth grade class. The school has 330 students in kindergarten through the eighth grades, 52 of whom are in the bilingual program. It functions as an "alternative" school, offering in its mainstream program at least a more open-ended and inquiry-based educational program than that found in most schools.

In September, the combined seventh-eighth grade had seven students; by January, the number had grown to 20. Traditionally, the students in this class take their core academic subjects (e.g., language arts, mathematics, social studies) in Haitian Creole from their classroom teacher, and instruction in English as a Second Language from an ESL teacher. Academically, the students range from a few who function approximately two years below grade level to those who cannot read or write in either Creole or English. During the year, science was taught three times a week for 45 minutes each in Creole.

The classroom teacher is a native speaker of Creole and is fluent in English. She has taught in the bilingual program for several years. Prior to the 1988-1989 school year, she had only occasionally taught science.

High School Basic Skills Program. The second classroom was in a large urban high school. The school serves 2700 students and is comprised of several "houses." The bilingual program occupies its own house and serves approximately 250 students, or about 10% of the student body. While the number of language minority students at the high school has remained relatively stable over the last ten years, the ethnic background of the students has changed as immigration patterns have changed. In 1977, three-fourths of the language minority students were Portuguese and Hispanic, and one-quarter were Haitian, Greek and Iranian. Today, 42% are Haitian, 24% are Hispanic, and 10% are Portuguese, and the remaining 24% are Chinese, Vietnamese, Korean, Indian, and Eritrean.

The high school offers bilingual education that in many cases mirrors what is available in the regular monolingual program (e.g., general science. biology, environmental science, basic math, pre-algebra, algebra, and geometry). These classes are offered in French/Haitian Creole, Portuguese, Spanish and Chinese. In addition, the bilingual program offers a Basic Skills program for those students whose low academic and literacy skills prevent them from participating in the regular bilingual program. This is the program in which Cheche Konnen was pilot-tested.

The Basic Skills program is for the academically weakest students, those who are at greatest risk for dropping out or school failure. Some of the students in the program were not able to read or write in their native languages, and most had only the most rudimentary mathematics skills and no previous exposure to science. There were 22 students in the Basic Skills program in the 1988-1989 school year from a variety of linguistic and cultural backgrounds. Six language groups were represented: Haitian Creole, Spanish, Portuguese, Amharic, Tignrye, and Cape Verde Creole.

Four teachers worked together in the Basic Skills program: two math teachers, an ESL teacher, and a social studies teacher. We worked directly with the math teachers who co-taught science and mathematics four times a week during back-to-back periods of 45 minutes each.

One of the teachers is a native speaker of Haitian Creole, is fluent in English, has a working knowledge of Spanish, and had taught science on occasion in the regular bilingual program but has no special training in it. The other teacher is a native speaker of English, has a good working knowledge of Creole and Spanish, and had never taught science before.

Teacher Workshops

To prepare the teachers, we held a series of twelve teacher workshops during the summer of 1988 and the 1988-89 school year. The workshops were explicitly designed to respond to the expressed needs and interests of the teachers. They covered topics that the teachers and researchers together identified as important: science and mathematics content appropriate to an investigation (usually contextualized in an activity), methods of scientific investigation (e.g., observation, experimentation, theory building/elicitation), science and mathematics linkages (e.g., collecting, analyzing, graphing and interpreting data), computer use (word processing, graphics, statistics software, and custom built Hypercard applications), and relationships between literacy and science. In addition, the workshops were used extensively to design and develop investigations, critique activities, and elaborate related literacy activities.

During the school year, we met with the teachers approximately twice monthly. One was a general meeting which all three teachers attended. At this meeting, we would discuss and critique what had happened in the previous month, share information across classrooms, and plan at a general level the next month's activities. Once a month the researchers would also meet individually with the teachers from each classroom. At these meetings, we would make specific plans for the implementation of an investigation and address any problems specific to that classroom. For example, because the high school had several language groups, the teachers experimented with different grouping arrangements in order to find those that were most effective (e.g., cross language grouping, grouping by interest, grouping by ability, and grouping by language which proved the most easily manageable). This problem was addressed over the course of several months in meetings with the high school teachers.

Investigations

Over the course of the year, the researchers, in consultation with the teachers, developed several investigations around the theme of water (e.g., water quality, water treatment, water conservation, and aquatic ecosystems). In the Cheche Konnen model, investigations are meant to serve as resources and references for teachers, not as a curriculum or a set of lesson plans per se. Each investigation includes background information for the teachers, suggested scientific activities, suggested ways of linking science, mathematics and literacy, and resource and reference material. Above all, however, the investigations are meant to be catalysts of class-initiated inquiry. An investigation establishes a context for pursuing a wide range of questions in its topic area. With this in mind, one of our expectations is that an investigation will necessarily be implemented differently at each site.

Data Sources

Our analysis of the first year's implementation is based on four convergent sources of data:[2] classroom observations (encompassing field notes, transcriptions of classroom audiotapes, and classroom videotapes), notes from meetings with teachers, interviews of teachers, and teacher- and student-produced texts.

Classroom observations. Classes at both schools were observed frequently. At the high school, approximately 70% of the classes were observed; in the seventh-eighth grade class, approximately 80% were observed. Audiotapes were recorded for approximately

80% of the observed classes; field notes were written for all observed classes. Observers noted classroom activity and discourse relating to science, mathematics and literacy, including classroom discourse, social interactions, blackboard writing, and patterns of classroom organizational structure. Limited videotaping was also done in each classroom.

Meeting notes. Notes were taken during and written up for all meetings with teachers. The content and progress of the conversation, particular concerns that arose, plans for the future, and the like were noted.

Teacher interviews. Teachers were interviewed once during the year. The seventh-eighth grade teacher was interviewed in late March; the high school teachers were interviewed in late May. The interviews were audiotaped and then transcribed.

Teacher/Student texts. We have copies of most of the texts produced by students and teachers during the course of the school year. Students' texts include their notebooks, letters, reports, spreadsheets, pictures, and final projects. Teachers' texts include reading texts they developed, worksheets, data collection sheets, tests and quizzes.

Two Case Studies

In our analysis we will be concerned with two levels of contrast. One is the contrast between the two classrooms in which we worked. This contrast revolves around the congruence (or lack of congruence) between the goals of the teachers and the goals of the model, and the effects of this on the kinds of science learning and literacy that took place in the classroom. At this level of contrast, we will be describing two cases, the K-8 class in which the teacher's goals were congruent and the high school class in which the teachers' goals were not congruent with those of the model. The result was two divergent interpretations of what it means to do science, interpretations which also had consequences for the kinds of literacy that were practiced in the two classrooms.

The second contrast is a within classroom contrast that emerged over the course of the year at the high school. It is this contrast that has helped clarify for us some of the critical characteristics of an investigation that make it a powerful model both for science and for literacy, even in a context where for the greater part of the year the model was not succeeding.

Case Study #1: The 7th-8th Grade Water Taste Test

We begin with a quote from the classroom teacher recorded during an interview we had with her in March 1989. We asked her about her goals in teaching science, specifically with regard to what she wanted her students to learn. She responded in the following way:

> Generally, one of my main problems whenever we get to science is to stay off the subject of home explanations of the way things happen. It's like if you want to talk about evolution, for example, the kids get mad, then you have to get all the way into their religious teachings. I think that's probably one of the things that I think about -- getting away from folk beliefs or religious beliefs and replacing it with something else.

In her remarks, the teacher directly focuses on changing her students' habits of mind as her main goal, away from folk beliefs to more scientifically-based explanations.[3] Later in the interview, she elaborates this idea to include analyzing and understanding relationships, and verifying those relationships through observation and experimentation.

Clearly, the teacher's goals mesh nicely with the top level goals of Cheche Konnen. But, in practice, how were they realized? What kinds of opportunities were created in this classroom for authentic scientific inquiry and purposeful literacy? To answer this question, we turn now to an analysis of an investigation undertaken in her class that stretched over several months, the Water Taste Test. The description that follows is a reconstruction based on classroom transcripts, field notes, and texts and graphs that the students produced.

For the better part of the year, the students studied the chemistry, biology, and ecology of local water sources and their problems. In this context, the class decided to investigate the basis for problems they believed existed in their school's water supply. The investigation had three stages, a class taste test, a junior high-wide taste test, and an analysis of the water in the school's fountains. The stages were not pre-determined, but evolved directly from the results of the students' own activity.

The investigation grew directly out of a strongly held belief among the students that the water from one fountain -- the third floor where their classroom was located -- was superior to that from other fountains in the school. To determine whether they actually preferred the third floor or only thought they did, they decided to do a class "blind taste test" of the water from the first, second and third floor fountains. Neither the teacher nor the students knew whether the results of the test would in fact confirm or challenge the class' belief. The class' initial problem posing and planning makes it clear that the purpose of the investigation fit closely with the teacher's express interest in challenging her students' folk beliefs.

The class designed the blind taste test based on a model they had learned earlier in the year as part of their introduction to science. Several students were dispatched to collect water from the three fountains and the teacher then labeled the water jugs A, B and C out of sight of the class. Before tasting the samples, the students completed a questionnaire in Creole to determine their fountain preferences and habits: (1) Where do you prefer to drink from: the first floor, the second floor, or the third floor? (2) Where do you drink from most often? the first floor, the second floor, or the third floor? Then after tasting the three water samples, they answered the last question: (3) Which water do you prefer: A, B or C? The students fully expected that their pre-taste test preference would be confirmed and that the third floor would, in their own words, "win."

Following the taste test, the class tabulated their data. Standing at the board, the teacher elicited each student's data and entered them into a table (see Table 1).

Insert Table 1 about here

By the time data tabulation was completed, little time remained, but the import of the results was registered. First, the teacher established which floor the class preferred and then she revealed the secret:[4]

TEXT 1
1 Teacher (T): OK, I'm going to give you the secret. According to what we see,
2 which do people prefer?

3 Maryline: B.

4 T: OK. Everyone says they prefer the third floor, right? And now we have three
5 here (under A), seven here (under B). Do you want to know what A was?

6 Marie France: Yes!

7 T: (...)[5]

8 Eclide: May I say? A was the third, B is the second, C is the first.

9 Frantzy: A is the third.

10 T: Nope. How many say A was the first floor?

11 Student: Me, I don't say anything.

12 T: How many say B is the second?

13 Student: Yes.

14 T: How many think C is the second? (Hands up.) OK, the first floor is B.

15 Students: (Shouting) Ohhhh!

16 Marie France: Yeah, we won! We won!

17 Carlo: It's lies you're making, you spoiled it, the thing didn't come out right.

The class' findings were as follows: whereas most of them thought they preferred the third floor (8) and drank most often from the third floor (10), in the blind test most of them (7) chose the first floor. As it happens, the first floor is the one which, in the students' mythology, is the worst of all because it's the one 'all the little kids slobber in"! The data struck the teacher as well as some of the students as screwy, a technical term for bias. One student (Line 17) was concerned that the results "didn't come out right." The teacher was suspicious, too, that the students had somehow biased their data by talking among themselves about which sample was which. So, on the teacher's part there was skepticism that the results were not valid. And on the students' part, there was horror at the idea that the first floor could possibly be the best. It just did not fit with the school mythology, with what the students themselves believed. But, as we shall see, the class' concern about the validity of their data will turn out to be important to their subsequent activity.

In the next class, they represented their data graphically. After reviewing the tabular data which were still on the board, the teacher invited the class to suggest ways to represent the data, prompting them with a model of a simple bar graph they had used earlier in the year:

TEXT 2
1 T: Yes, there was that, but don't you remember the way we arranged the
2 numbers?

3 Kenia (at the blackboard): We put, as if I would say to you, like with this, you
4 put first, second and third (...), and after that we put how many people are in the
5 class. We put (...) there, how many in this class, now.

6 T: (...) Can you graph it? Is there anyone who knows what Kenia's
7 doing?

8 Students: Yes. No.

9 T: What are "first, second and third"?
10 K: The first is the number of people there are.

11 T: No, first what?

12 K: First floor.

13 T: What does this (referring to the graph as a whole) represent?

14 K: What they prefer.

15 T: Which column on the board are you doing? Before they drank or after?

16 K: Before they drank.

In this episode, the teacher is questioning the student about the meaning of her graph (shown in Figure 1), not merely to see how much the student understands but also to establish a common ground ("Which column on the board are you doing?"), since it is the student who has chosen which set of data to represent. Through their dialogue, the student's graphical representation is linked directly to the tabular data collected in the previous class. It is almost as if the teacher and student together are modelling this data representation process for the rest of the class.

Insert Figure 1 about here

The transcript continues:

TEXT 2 (cont.)
17 T: Kenia's begun a graph.

18 Andrew: She doesn't know what she's doing.

19 T: She knows what she's doing. It's called a graph. It has two variables. One
20 is the floors, the other is the number of people. And she says it represents
21 what's in the first column. The column is (...) what people say they prefer.

The teacher first interprets Andrew's criticism as a flippant and potentially hurtful remark, but as we get further into the transcript, it will become clear to her that Andrew meant what he said. He believed Kenia was mistaken in her representation.

TEXT 2 (cont.)
22 T: What number does this represent?

23 Student: One.

24 T: One what?

25 Eclide: One person.

26 T: One person who says she/he preferred the first floor. And this? What does
27 it represent?

28 Student: Three.

29 T: Three people who say they prefer the second floor. And this?

30 Student: Two.

31 Students: Eight.

32 T: Eight people who say they prefer the third. That's the way Kenia has
33 arranged the table.

34 Andrew: Josiane, you can have another...

35 T: Mm hmm?

36 Andrew: There's another way you can do it.

37 T: OK, if you want to do it another way, go ahead.

38 Andrew: It's almost the same as this one (Kenia's).

In Lines 34-36, Andrew has transformed his earlier negative bid (Line 18) into a positive bid for the floor. For the moment, it appears he has subordinated his problems with Kenia's graph to his invention of an alternate representation (Figure 2), even to the point of suggesting that his and Kenia's are nearly the same.

Insert Figure 2 about here

Andrew's representation, however, is problematic and its meaning is not explored in any depth even though some of the students express unhappiness with it. The teacher deliberately shortcircuits the criticism because, as she told us later, she did not want his invention -- which she viewed as an achievement -- to be undercut. This also helps explain her rejection of his earlier bid which was expressed as a negative judgment of another student's work.

Cognitively for Andrew, his invention of an alternate representation marks a significant moment, for he has begun to think critically about the relationship between different data representations (e.g., tabular and graphical data). He has recognized, for example, that there is not just one representation for a given set of data but possibly many, and that the adequacy of any one representation depends on what it is you are trying to show or on what you think your data mean. He has, in short, begun to develop a mathematical belief system, one that is truer to mathematical ways of thinking than is most school math. As it turned out, his problem with Kenia's graph derived from his misunderstanding what she was representing:

TEXT 2 (cont.)
39 Andrew: She did the picture badly, Kenia, because...

40 T: Who?

41 Andrew: Kenia. Here's what I don't understand about hers. It's the second
42 floor that, that, the first floor they like best. But she marked the first floor -

43 T: No, no, no, no, no. That's not the same information. That's the
44 information before they tasted the water.

45 Andrew: Oh, I see.

Nevertheless, here, as before, Andrew is thinking mathematically and expressing his understanding concretely in terms of the data, what he thinks they mean, and how he thinks Kenia has misrepresented them. Having articulated his confusion, he was then shown its source, which he understands immediately. Following this episode, the teacher directed the class to do a graph for the post-taste test results. One student, Carlo, immediately asked Andrew for advice. A little later on, another student, Evens, also sought out Andrew for help. It seems that Andrew, by offering a new kind of representation and questioning the validity of Kenia's graph, established himself in the eyes of his peers as an expert in graphical representation.

Having completed the in-class taste test and tabulated their data, the class found itself faced with a new problem, one which arose directly from their own activity (i.e., it was not imposed from without either by the teacher or a text or a curriculum). The problem was this: Were their data reliable or not? The problem was never articulated in precisely those terms. But, based on the class' reaction to their data, it seems reasonable to suppose that what motivated their subsequent activity was a certain mistrust of the data they collected -- the teacher for one reason, the students for another. So what did they decide to do? Another taste test, of course, but this time of the school at large. Again, although not articulated explicitly as a question about the reliability of their data, their action is a scientifically sound one -- to redo the experiment, only this time with a larger sample.

In the next class the students planned the school-wide taste test. The teacher opened the planning session simply by asking: So what do we have to do to pull this off? From that moment on, the students took more or less complete charge, raising issues, and assigning responsibilities. First, they tackled some of the logistics: where to do the taste test, when, and on whom. With some prodding from the teacher, the class decided to limit the taste test to the mainstream seventh and eighth grade classes only. They discussed the issue of water: how to collect it, how to hide the identity of the sources and, crucially, how many fountains to include, deciding on the same three as before so their data would be comparable. They worried about bias in the voting process: what if some students voted twice, and so forth. They discussed what questions to ask each student, which the teacher wrote on the board. As class came to a close, every student took responsibility for some part of the study. Some were responsible for creating the sign to advertise the taste test. Others were responsible for putting the questionnaire on the computer in English, and so on.

There are several points to note here. First is the initiative and independence shown by the students in planning the taste test. Again, this fits well with the teachers' interest in promoting students' active engagement in their own learning. Second is the literacy that grows directly out of the scientific venture. Students are engaged in producing texts (e.g., the sign and the survey) that have a purpose as well as an audience. Third is the soundness of their reasoning in confronting important issues in experimental design: issues of bias and of comparability. Fourth is the collaborative spirit of virtually every class activity. There are several obvious cases, for instance, when the students took on different tasks to prepare the junior high taste test, or when the two students asked Andrew to help them with their graphs. To be sure, there are times when the teacher stands front and center, but this is usually to model some new form of knowledge or scientific or mathematical practice. But, by and large, the whole class activities are done collaboratively, as the students and teacher collectively work to find an answer to their question by collecting, tabulating, representing and interpreting data.

The Junior High Taste Test took place on February 14, Valentine's Day. The students set up a table in the cafeteria. Next to it they placed a large sign announcing the taste test: "Take the Water Taste Test...Get one cookie for your vote." As students came up to the table, they were handed a questionnaire and three water samples. Approximately 40 students participated. For the class, the taste test proved an exhilirating experience because they had initiated and organized it, and because they were both recognized and appreciated by the other students for their effort. They were, at least for the moment, no longer on the margin of the school community. As proof of their accomplishment, the principal asked for a report of the results that he promised to read over the PA system.

The taste test completed, the students returned to class to tabulate their data. The teacher asked three of the students to tabulate the data on their own while the others worked on other projects. The three worked out a procedure whereby two students shared the reporting of the data and the other tabulated it at the board. They reported their results to the teacher who then asked them to combine the class' data with the junior high data. Another student located these data in his notebook and shared it. They added up the numbers to find that the class results were confirmed: the majority of students preferred the first floor in the blind taste test but thought they preferred the third! With help from an aide, the students then composed an annoucement in English for the principal to read over the PA system (unfortunately this text has been lost, hence its omission). In the next class, the whole class retabulated the data. They then graphed the combined data and hung the bar graphs on a kiosk outside their room. Sometime later, a student composed on the computer in Creole the following summary:

> Nou tap fe yo eksperyans sou dlo nan lekol la. Nou jwenn ki dlo nou pi renmen nan lekol la. Nou fe yon tes pou lot timoun yo. Gen nan yo ki te chwazi sa yo pi renmen yan. Nou te jwenn premye flo ki pi bon, nou te we twazyem flo to (sic) dezyem.
>
> Translation:
> We did an experiment on the water in the school. We found out what water we liked best in the school. We did a test for the other kids. Some of them chose the one they liked the best. We found the first floor was the best, we saw that the third floor was second.

Here the student very concisely reported on the class' "experiment." In fact, it is interesting that she chose to lexicalize what they did in this way since all along it had been referred to as a "taste test" rather than an experiment (although the term "experiment" had been discussed earlier in the year in other contexts). The use of this term is neither accidental nor superficial. Note how in the fourth sentence she points out that some of the kids "chose the one [they thought] they liked the best," as if to underscore the critical experimental comparison between stated preferences and actual preferences. Still, the discourse is largely narrative in style, a report of events or actions with no explicit analysis or explanation. But the events reported have an interesting structure, one which suggests that the student may be struggling, however tacitly, with a new way of writing or a new discourse form, that of written scientific discourse, which seems to derive directly from the structure of the investigation itself. First, she establishes that what the class did was an experiment. She then states the purpose of the experiment (to find out which water they liked best), reports that a test was done for the other kids (admittedly without explaining why this was done), and then in the final sentence summarizes the test results. The form she has crafted, although lacking in many of the explanatory, theoretical and evidential conventions of scientific writing, builds on her narrative strength and begins to tell a story about students doing science. It is all the more remarkable in light of the fact that no observed class time had been devoted to explicit instruction (or coaching) in scientific writing.

The class now had similar results from both taste tests. But the findings gave rise to a new problem: *Why* did the students choose the first floor fountain over the other floors? To determine the source of the students' blind preference, the class embarked on a study of school's water fountains. This study had some problems, not the least of which was that it ran up against spring vacation which was costly in terms of momentum. But in the end, the class investigated three variables: temperature, salinity and bacteria. This naturally limited the conclusions they could draw, although they did find clear differences in water temperature and uniformly high bacteria counts. Despite these problems, this phase of the investigation was productive in terms of the students' scientific activity, as the following example, reconstructed from field notes, illustrates.

Over several days, the class tested the school water for bacteria using Millipore Total Count samplers. These are prefabricated nutrient rich pads that are soaked in the water that is being tested and then incubated for several days. The surface of the pad is a grid on which the bacteria, if there are any, grow. To calculate the total bacterial count, students count the spots or colonies that grow on the grid. As groups of students tested the school water samples, Eclide proposed an experiment. Earlier in the year, the class had learned how to test untreated water (from a local river) for a specific kind of bacteria, fecal coliform. This entailed using a particular type of sampler (the "blue" sampler). To test the school's water, they used a different sampler, the one for treated water (the "white" sampler) which tests for total bacteria. Eclide wanted to know how the two samplers differed and proposed an experiment in which she would use both samplers for the same water to see what would happen. While this experiment may not fully answer the question she had posed, it is a beginning and demonstrates Eclide's understanding of the need for a base of comparison in experimental design. Being told they were different was apparently not enough; a well-designed experiment, she believed, would help clarify the issue. Eclide is now elaborating the teacher's goal to develop in her students a scientific attitude towards knowledge as she begins to question the authority of untested knowledge, knowledge she has been told and that she is expected to trust, the very kind of knowledge, in short, that schools typically dispense.

Discussion

For everyone concerned, the Water Taste Test was a successful, if at times imperfect, investigation. Why?

At the heart of the investigation was the idea, one to which the teacher was deeply committed, of scientists being, at least in part, questioners of received beliefs. Here the teachers' goals meshed perfectly with the investigation's purpose. The class believed that the third floor water was superior to that of the other floors. But were there any scientific grounds for supposing this was true? That was the key, albeit implicit, question underlying this investigation.

The process by which the class then explored its beliefs took the following form. The first step was to assume the truth of the class' opinion and, implicitly, to consider some of the logical consequences of holding that opinion: namely, that if it were true, then other students would share it and, in a blind taste test, the third floor would be the floor most favored. This at least was the de facto expectation. Next, they experimented to find out whether their expectation would indeed be fulfilled. The data they collected then became the ground on which they reasoned. Finally, each step in the investigation gave rise to a new question which in turn presented new problems for the class to consider (e.g., bias, comparability of data). Thus, although well-defined in terms of its object (to determine which water was best), the investigation was ill-defined in terms of its "scope and sequence," to borrow a curricular term. But this very fluidity is what made it possible for the class to explore the limitations of their initial study and to expand their study from one that sought to demonstrate differences to one that sought to explain those differences.

The investigation also changed the typical teacher-student relationship in which the teacher knows a priori the entire sequence of things to be learned and how they are to be learned. Throughout the investigation, in contrast, both the teacher and the students were co-investigators; neither knew a priori the answers to their questions or even the direction(s) in which their initial study would evolve. This, as will be seen in the second case study, turns out to be an important feature of investigations. Together and through direct contact with the phenomena they were investigating, the students and the teacher *produced* and *evaluated* the knowledge they needed to answer their questions. And they did this without having learned *about* science, that is, without having learned a specific vocabulary or set of facts preliminary to actually *doing* science. Yet they still confronted significant issues of bias, comparability of data and representational accuracy as these arose in the context of their own purposeful activity. And in the process they began to build a common ground of scientific experience and discourse.

The investigation also led to purposeful and multidisciplinary literacy in the classroom. Mathematics, of course, was key. Students had several occasions to develop representations for their data, to translate from numerical or tabular representations to graphical representations, and they became increasingly facile at this. As the investigation expanded beyond the confines of the classroom, the students also needed to develop texts in English. To advertise the taste test, they created a large sign. To collect their data, they developed a questionnaire in English. To report their results to the school at large, they composed an announcement for the principal to read over the PA system. In addition, throughout the investigation, the students' discourse was developing. Students learned to talk about ways of obtaining and summarizing data, using terms such as eksperyans (experiment), tes (test) and grafik (graph); they also mastered the use of special terms such as fecal coliform and bacteria colonies, and were introduced to terms of measurement such as centigrade, fahrenheit and millileters. Not only had they experienced scientific inquiry directly, they had also begun to acquire the language to talk about it (cf. Heath, 1983).

Socially, the investigation had benefits as well. It helped bring the students into contact with their native English-speaking peers, which brought them a sense of pride and belonging and helped give value to their work. One student commented to them during the junior high taste test, "You know, what you are doing for us is very important." Not only were the other students impressed but, later as the investigation progressed, the other teachers were as well, remarking to the class' teacher that her students were going on and on about "this thing called fecal coli --." And, finally, the students' work was validated from outside the school as the chemist at the local water treatment, when told of the high bacteria counts from the school's fountains, offered to come and test them on site but only if the students promised not to publish their results in the local newspaper!

In the seventh-eighth grade classroom, then, the teacher's goals were congruent with those of the Cheche Konnen model. The teacher engaged the students in inquiry, focusing in particular on the critical function of science in challenging unexamined beliefs. A collaborative spirit pervaded the investigation. And, finally, mathematics and language were both integrated into the process of doing science to accomplish specific purposes. It is worth noting, perhaps, that the teacher felt she did not create as <u>many</u> opportunities for mathematics and writing as were possible in the context of the water taste test investigation.

Case Study #2: The High School Basic Skills Program

The high school in some ways provided the critical test of the Cheche Konnen model for it was there that the model was at first interpreted one way, antithetical to the goals of the model, and then interpreted another way, consistent with the goals of the model. For much of the year the model was wholly assimilated into the existing classroom context (cf. Michaels & Bruce, 1989), defined as we said earlier in terms of the teachers' goals for what they wanted their students to learn and the translation of those goals into specific teaching practices. During this period, the teachers' goals and the teaching practices to which they gave rise were not consistent with those of the model. The result was that the model's goals for promoting inquiry, collaborative learning and purposeful literacy were not met. Later in the year, however, a transformation took place in the kind of science and literacy that were practiced in the classroom, from school science and English as a Second Language (ESL)-based language development to scientific inquiry and communicative literacy. In this case study we will analyze the character and roots of these two interpretations, looking closely at the effects of teachers' goals on the science and literacy that are practiced and at how particular characteristics of an investigation can effect important changes in the roles that teachers and students assume in the learning process.

At the beginning of the project, we believed that our goals and those of the high school teachers were in harmony. We believed this for several reasons, chief among which was that the teachers, by their words, seemed to understand and agree with the stated goals of the project. In practice, however, they enacted an academic program very different from the one we were proposing.[6] For example, when we talked about integrating literacy into science, they expressed their concern for the special needs of their students, namely, learning to speak, read and write English. From our perspective, these goals were perfectly compatible with those of the model, even encouraged. We believed that scientific inquiry would provide a powerful context for meaningful literacy practices. However, as the year progressed, we realized that by literacy the teachers had in mind basic ESL instruction, emphasizing decontextualized language use and development.

As the year wore on, the teachers and researchers alike grew frustrated with the project's progress. To address the group's frustration, we planned with the teachers a final investigation in which we tried to accommodate the goals of both parties. The result was an investigation that not only promoted authentic scientific inquiry but also improved the quality of the literacy practiced in the classroom. In this section, we will first analyze how and why for the better part of the year at the high school the Cheche Konnen model took the form of school science rather than investigation-based science. We will then analyze the final investigation, with an eye toward understanding how and why it was able to transform the kinds of science and literacy that were practiced in the classroom in a way the earlier investigations were not.

As in the first case study, we begin with a quote from one of the teachers recorded during an end of the year interview.

> "These kids have traditional needs -- basic reading, worksheets, writing. They need to learn how to put sentences together, (...) how to turn questions into answers (...). They must learn how to succeed in their other classes."

The high school teachers' goals derived at least in part from their assessment of the realities of schooling. They knew only too well the context of instruction into which their students were to be graduated: a world of worksheets and standard textbook-based learning. One of their primary goals, therefore, was to teach their students how to succeed in that world.

One effect of the teachers' goals was to transform the Cheche Konnen model into its opposite, the very kind of science and language development against which the model had been defined, namely, school science dominated by teacher-led lecture and discussion and by rote memorization and recitation of vocabulary and procedures. In this form of science, experiments are reduced to procedures, the execution of which leads to answers already known (e.g., to the teacher, the culture). Students learn about science more than they learn to do science. This model of science learning (or of learning in any discipline, for that matter) is ubiquitous throughout American education (Mullis & Jenkins, 1988; Sizer, 1985). It is, in fact, the archetypal model for American education, and in many places, it is the desired model. Interestingly, it is often most prevalent in contexts where its failure is most conspicuous, namely, in inner city schools, special education classes or, as in this case, language minority classrooms. Nevertheless, it persists and conditions the way teachers and students alike think about school, its purposes and its methods.

A second, not unrelated, goal of the teachers was to teach the students basic spoken and written English, again so they could function in school and society. Their model for achieving this derived from ESL instruction, and emphasized practice in simple English grammatical constructions, pronunciation, spelling, and other word- and sentence-level skills. ESL fits easily within the construct of school science; students can routinely practice language usage in the context of answering textbook questions or completing worksheets.

In science class, language development consisted mainly of exercises requiring students to turn questions about science content into statements, to practice formulating and writing various kinds of sentence constructions (e.g., comparatives, descriptions), to alphabetize science vocabulary words and use them in sentences, and to generate lists of synonyms for words they already knew.

How specifically did the teachers accomplish their goals? How did they interpret the Cheche Konnen model in light of these goals? Put a little differently, what forms did science and literacy take in their class? Our analysis of their interpretations is based on reconstructions from field notes and analyses of classroom transcripts and texts (those created by teachers and by students).

After some experimentation with different class groupings, the twenty-two students were divided into three groups based on language. There was a Haitian Creole group, a Spanish/Portuguese group, and an English group comprised of those students whose English was more advanced as well as those whose native language was something other than Spanish, Haitian Creole or Portuguese. Lessons typically took one of two forms, either organized around a text and worksheet or around a lab and worksheet. When organized around a text, the lesson had the following elements: an introduction usually through an English text written by the teachers, vocabulary review, reading of the text (accompanied at times by translation), answering questions related to the text, and writing of the answers in correct English form on the board and then copying them into notebooks. Labs were sometimes introduced by a text and were always organized around a worksheet, (e.g., a data table designed by the teachers and filled out by the students), an initial demonstration (e.g., this is how you do the pH test), students' doing the lab, and a review of the results often accompanied by language development exercises of the type previously described.

There was always the sense in these lessons that there was a correct answer to be found and that the teachers knew what that answer was. We offer an excerpt from one representative class transcript as an illustration. The excerpt is taken from a class conducted in January, well into the first year, in which students are introduced to litmus paper as a method for determining the pH level of various liquids (e.g., water, Coke, lemon juice, milk, baking soda, vinegar). This activity is part of a more comprehensive investigation into water quality that also includes the study of other factors such as bacteria, salinity, and turbidity and ecosystem relationships. The goal of this class from the researchers' point of view is for the students to experiment with litmus paper, understand its strengths and weaknesses as a measurement tool, collect data that manifests variability, discuss the possible sources of that variability and, finally, arrive collaboratively at a representative pH level for each substance tested. In subsequent classes, the students were to explore the pH of various waters they had collected (e.g., home, school, river, pond, rain, spring water) and the effects of acid on various objects.

The transcript is of the discussion in the Haitian Creole-speaking group. The language used is English, except where indicated (C = Creole; E=English) immediately preceding the text to which the designation refers. Two teachers were present, one of the science/math teachers (referred to as "T") and the ESL teacher (referred to as "T2") who assisted them. A worksheet, Table 2, is the organizing text for this class.

TEXT 3

1 T: Did everybody get a sheet? Now, everybody has one? You have a pen?
2 Come sit closer, guys, sit closer. Remember what we were talking about before
3 we left the other day? We were talking about pH; remember we said we were
4 going to learn some chemistry today? Who remembers? Who remembers?
5 (Writes on board: pH, acidity, alkalinity.) OK, al-ka-lin-i-ty. OK. Samson isn't
6 here. Where are you going, Roudy? OK, one for you. Come in here, we've got
7 to get started. What we're going to do today, we're going to test for pH.
8 Remember I was telling you we're going to use those little pieces of paper, ok, to
9 see which one is more acidic compared to another one. And I'm going to do a
10 sample for you. This little piece of paper, when I put it into one of these liquids,
11 it changes color. (Repeats in C.)

12 Sofia: So it's going to change color?

13 T: Yes, because, let me give you, pass this (the pH color chart) around. OK.
14 You look at it, share it, OK? Sofia, look at it and pass it around because we
15 only have three. (Repeats in C.) You see the numbers on there, ok, its going to
16 change color. You see the numbers and colors (...).

(Brief interruption.)

17 T: OK, do you see the numbers? (Repeats in C.) And colors? The paper is
18 going to change color...

19 T2: Ahh...

20 T: If it turns green ... (C) If it turns green, what number is it?

21 Samson: 8.0

22 T: (C) 8.0, green. (E) So that's what you're going to have to do. You're going
23 to...

24 T2: 7, 8, or 9, right?

25 T: 7, 8, or 9. (C) Each liquid may have a different number. You're going to

have to decide on the number. Martine, do you understand? If it's red, it's number three; if it's green, it's number eight. (E) Did you read at the top of the paper? (Referring to worksheet) It says, "Take a piece of litmus paper." Everybody should have some litmus. Pass them around, give everybody a few. Litmus (writes "litmus paper" on board). See that paper? It's called litmus paper. Ok?

(Students repeat the word and T2 corrects their pronunciation.)

T: I have your book. I'm going to give them a table because-

T2: Over here.

T: Kerline, here's your book. Everybody have litmus paper? What we're going to do, we're going to take the litmus paper and dip it into the water. Its going to change color. By changing color, we're going to... (C) Using the color, we're going to make a decision about pH level. OK? (E) Sofia, according to the color, you're going to say what the pH level, if it's that red (pointing to color chart), the pH level is 3. OK? So what I'm going to do, what you have to do, you have to put the pH level in here (referring to worksheet), ok, look on your paper where it says "Hypothesis pH level" and then you have to tape the piece of paper right here. OK? We're going to tape that piece of paper on your notebook, after it changes color.

T2: Hypothesis, is that where you tell what the number is?

T: Yes, but later on we're going to compare to see if we have the same color. You never know, some people might be color blind.

The episode recorded here demonstrates that a model of school science, as opposed to investigation-based science, is in operation. To begin with, the goal of the lesson is to teach the students how to use litmus paper and for them to then complete the worksheet. This goal in and of itself is not antithetical to the goals of investigation-based science. It is only when it is enacted in the context of a particular set of assumptions and purposes that it becomes so.

In general, the transcript shows that the pedagogical approach is strongly teacher-centered, with very little actual teacher-student interaction. Any interactions are teacher-initiated, except for one (Line 12) where the student is attempting to verify that she has understood the teacher. For the most part, however, the students do not ask questions; in fact, the teacher does not pause long enough for students to ask questions (cf. Rowe, 1986), as if they are not expected. Most of the teacher's effort is spent in making sure that everyone has understood the litmus test procedure, a realistic concern given that the group includes the Haitian students and two students (one from Eritrea, one from Ethiopia) with whom she must communicate in English. However, the emphasis on understanding at the procedural level completely dominates the classroom discourse throughout the class (see continuation of transcript below). There is no discussion, for example, about what the pH levels mean, even in the familiar context of introducing new vocabulary. Words such as alkalinity, acidity, and litmus are written on the board but the students's attention is directed toward their pronounciation, not their meaning. As other transcripts demonstrate, one result of this procedural emphasis is that when the students do speak, their answers are short and virtually monosyllabic, usually in response to some kind of comprehension check.

Insert Table 2 about here

Nowhere are the teachers' assumptions and purposes more obvious than in the worksheet used in the lesson. As the organizing artifact of the lesson, the worksheet embodies certain assumptions about the task and what the students are supposed to do (and, implicitly, are capable of doing), the effect of which is to circumscribe their learning and the entire teaching/learning context in particular ways. The worksheet, entitled "LAB: Determining Acidity/Alkalinity" (Table 2), exemplifies how the teachers specifically reformulated the activity originally developed as an introductory investigation into teacher-centered school science.

At first glance, it is hard to see how this can be so. The third and fourth columns marked "(Hypothesis) pH LEVEL" and "ACTUAL pH LEVEL," respectively, seem to ask for a hypothesis and then a test. Specifically, the heading of column three suggests that the students are being asked to make hypotheses about the relative pH levels of common household liquids.[7] The heading of column four suggests that the students will record their litmus paper readings for each liquid next to their hypothesis and that some discussion about the basis for and evaluation of hypotheses will be entertained. This at least is how we interpreted the worksheet when it was handed to us at the start of class. However, as it turned out, this was not how it was intended or how it was used. As the teacher explained a bit later to the students, the column labelled "Hypothesis," is where they were to put the pH reading they got when they tested each liquid. The column, "ACTUAL pH LEVEL," was to be filled in at the end of class, based on information provided by the teacher. She would tell them each substance's "real" pH.

Viewed in light of their stated goals -- to help the students become competent at school tasks and in English -- this interpretation of the pH lab is not surprising. But it does undermine the purposes of the investigation-based model. Moreover, in its execution, it is not very successful in fulfilling even the teachers' goals: the students do not talk very much, and very little of the lesson is focused on understanding meaning. What seems clear from this example is that there was a fundamental tension between the teachers' goals and those of the model. What was meant to be an introductory activity that included some data collection, data exploration and discussion about issues of precision and replicability was reinterpreted as one in which there was a set procedure and a foreordained set of "right" answers, known by the teacher and dispensed to the students.

This was not, however, because the students did not uncover through their activity the kinds of problems that create opportunities for discussions of the kind we had anticipated. In the following excerpt recorded the next day, the class is reviewing their results and the teacher is telling them the "correct" answers. Interestingly, one of the students feels that the wide range pH paper (which detects gross differences in pH, for example from 2.0 to 3.0, but cannot distinguish finer differences from, say, 2.0 to 2.5) is not sensitive enough for their purposes. Instead of seizing on this and asking the student to explain her thinking or entertaining a discussion about precision, the teacher elaborates a lengthy explanation that closes off discussion, allowing the class to continue with the business at hand, namely, checking the correctness of their answers. Here the effect of the teacher's discourse is actually to marginalize the kinds of viewpoints and values central to the discourse of scientific inquiry:

TEXT 4
1 T: (E) Ok, I'm going to double check and do a test for each of them, for baking
2 soda, milk, vinegar, for each of them to check and make sure that you guys have
3 the right numbers. The colors may have changed a little bit because they dried
4 up, ok? But we should get somewhere close. And some of them, like Kerline
5 said, Kerline didn't put a number for orange juice, like Sofia, because they felt
6 that we didn't have that color in there. We have to talk about why. Ok, it has a
7 number but it might be 6.5, if its between 6 and 7...How about milk? What did
8 we get for milk?

9 Student: 6.

10 T: 6? Anybody else? Everybody got 6 for milk? What did you get?

11 Kerline: Nothing.

12 T: Nothing? Why?

Kerline explains in (C) that she did not write anything down because she didn't think the color of her strip matched any of the colors on the chart.

13 T: Let's see what happens. Should I stir the milk? (Laughter but no responses.)
14 Ok, what number? Did you get a number for that? No number for that? We
15 have to talk about that yet. Here is mine. Do we have anything in here? You
16 don't think it's close to a 6?

Frantzia: Yeah, it's a 6.

T2: Who else got 6 for milk? Samson got 6.

T: Why? See, what happens sometimes is that the number, the color, can be in between-

T2: You can't look in between.

T: because we go from 3 to 4 to 5 to 6, 7, 8, 9, 10. (She explains in C what she means by "in between" numbers using an analogy to money.) (E) You have something in between, 2.5, 6.5, 6.4. There is variation between 6 and 7, right Sofia? But on this one we can't see the variation. We jump from 6 to 7. I was telling the kids in Creole that its like the money: you have 1 dollar, 2 dollar, 3, dollar, 4 dollar, but what about the change in between? You could have 6 dollars 28 and 50 cents, right? So maybe that's why we don't have a number for -

Sofia: Excuse me? What do you mean we don't have a number?

T: For this one we don't have a number, but there is a number between 6 and 7, like 6.2, 6.3, 6.5, so there's variation in between.

Sofia: So it's got to be 6?

T: We'll say 6 or 7, so we have to decide 6 or 7, but we know if you did it completely there might be a number between 6 and 7. So, did you say 6?

Sofia: Yeah.

T: Who else said 6? Who else said 6? Ok, (C) do you understand? (E) Ok, so we're going to say 6. So we'll say 6. Milk.
(Teachers circulate and check that students have written 6 in the right place.)

There is the potential in this discussion for inquiry but rather than exploring the students' thinking, the teacher does the thinking for them, although not necessarily effectively. In fact, in Line 30, one student questions the teacher's reasoning when she asks, "What do you mean we don't have a number?" Up to this point the lab has focused entirely on getting a number and, in particular, on getting the right number. Suddenly, the rules seem to have changed, and the student leaps on this for clarificatic , a sign of how potent are the assumptions and values underlying the teaching and learning context. But all is set right when the same student in Line 33 concludes, quite correctly as far as the teacher is concerned, that "So it's got to be 6?" The opportunity to explore an issue the students will confront several times during the water investigation has been lost.

In this example, it seems that something more than what we have been referring to as the teachers' goals is at play. In fact, the teacher seems to sense the tension between the purpose of the lab as she has formulated it and the problem uncovered by the students. Once uncovered, the teacher seems not to know how to deal with it. For example, when in Lines 34-35 she says "...we have to decide 6 or 7, but we know if you did it completely there might be a number between 6 and 7," she is coming right up against the tension between her purposes and the problem posed by the evidence and she shows that she is at least sensitive to it. She does not, however, deal with it very effectively; indeed, it is hard to imagine what she thinks the students understand from what she has said since there has not been any prior discussion of alternative methods for measuring pH. In any case, when all is said and done, it is getting the right number that dominates the lab. That is afterall how she opened the period, Lines 1-3: "I'm going to double check and do a test for each of them (each liquid)...and make sure that you guys have the right numbers."

To this point, we have focused on how the teachers interpreted the Cheche Konnen model to fit with their goal of teaching the students to be competent in school science tasks. Now, we turn briefly to a representative example of how science was used to develop their English language skills. The week after the pH lab, the students and teacher complete a pH review worksheet (see Table 3).

Insert Table 3 about here

The worksheet consists of a text a few sentences in length and then a series of short answer questions. For example, toward the bottom of the page, the text states that "Ammonia has a pH of 11 and baking soda has a pH of 8." The students are asked which is more basic, ammonia or baking soda, and why. The following excerpt is a discussion of this task and demonstrates how science was used as a context for ESL instruction. The teacher has written on the board the statement "Ammonia has a pH of 11 and baking soda has a pH of 8."

TEXT 5

T: Which one did you put? Between ammonia and baking soda? Ammonia, ammonia? Wake up. You see ammonia is 11 and baking soda is 8, so we said ammonia is more basic. Ammonia, OK, alright. Ammonia. I don't see it in here (looking at students' notebooks) I don't see it in here. Which one is more basic? Which one? Well, write it down there! OK, alright. Why? How do you know? Who can change that sentence for me to give me an answer for how do you know, for ammonia and baking soda, using almost the same words. How can I change that sentence? Frantzia, can you help me? OK, OK, go ahead. (Frantzia goes to the board.) Let's change it to answer that last question about baking soda and ammonia. How can I change that sentence to answer how do you know about baking soda and ammonia? "Because the pH number of - "

12 Romaine: baking soda

13 T: Hold it! Hold it! "Because the pH number of baking soda ... " (Frantzia
14 completes the sentence with "is 8".) Why are you saying what is the pH
15 number? You're going to give it away.

16 Student: 8!

17 T: Is that what it is?

18 Romaine/Frantzia: Is lower-

19 T: I'm sorry. I'm sorry. "Is lower than..."

20 Romaine/Frantzia/Sofia: "The pH number of baking soda..." (Frantzia now has written on the board "Because the pH number of baking soda is lower than the pH number of baking soda.")

21 T2: What are we talking about here?

22 T: How are you going to do that? Don't you know? Maybe we should make
23 this "higher" (referring to the word "lower" in the sentence); if we say "higher"
24 we have to say that the pH number not of baking soda, but of - ammonia, we
25 should put "ammonia" right here, so we can use "higher" over there. So don't
26 change this. Yeah, put ammonia in there. (Explains in C) (Frantzia makes the
27 corrections to her sentence.) Alright! So what did we say? "The pH number of
28 ammonia is higher, not equal, is higher ..."

In this segment, the teacher has taken a comprehension task (which can actually be completed on its own without the experience of the labs) and adapted it for the purposes of teaching comparative English constructions. In this excerpt, like the others before it, the teacher already has in mind exactly what it is she wants the students to produce, namely, a particular form of the comparative (x is higher/lower than y). So, when at Lines 13-14, Frantzia formulates a phrase, the teacher jumps on it because it does not conform to her expectation. She objects to the inclusion of the pH number in Frantzia's phrase because that "will give it away" (Line 15), the "it" presumably being the comparison of "lower" or "higher" that is the real purpose of the exercise. But from what Frantzia has written ("Because the pH number of baking soda is 8"), borrowing from the teacher's initial, but partial, model ("Because the pH number is"), it is not immediately obvious how she planned on completing her sentence. For example, she may have planned on writing something like "Because the pH number of baking soda is 8, it is less basic than ammonia." The result of this exchange is confusion, as evidenced in Line 20 ("Because the pH of baking soda is lower than the pH of baking soda"). Whereas up to this point what mattered most was the actual pH level expressed as a number, now what matters most is the comparison expressed in terms of "lower" and "higher." The ground seems to be shifting under the students without their understanding the purposes of the activities they are being asked to perform. In the end, the teacher completes the exercise for the students, substituting "higher" for "lower" and rearranging other parts of the sentence, without articulating why these moves are important (which, from the students' perspective, they must be because that is the way the teacher wanted it). This example is typical of the language activities that were developed by the teachers for most of the year. Like the science they taught, it has a clear instructional purpose (clear at least to the tea _r), but no authentic, communicative purpose, and in the end seems not to achieve even th achers' goal to develop the students' English language skills.

By the time this lesson was taught, the students had been drilled for approximately eight hours on the pH levels of various liquids and what these levels represent about their relative acidity or alkalinity. The worksheet continued this rehearsal of knowledge isolated from any meaningful context. The students are simply practicing their knowledge about pH in the context of a standard school task, that of reading a text and answering questions, rather than formulating and exploring questions (e.g., about the sources of acidity in the environment and its effects) through experimentation and data collection activities. Nor does this set of lessons result in very productive literacy. If the goal were to practice speaking or writing connected discourse containing comparative statements, then an investigation focused on collecting data on the pH levels of the various waters in their community and on developing and evaluating theories of the sources of observed high and low pH levels would have led naturally to the very kinds of comparison that were the object of the teacher's lesson. In this way, both the goals of scientific inquiry and literacy would have been more satisfactorily met.

Our intention in this first part of the high school case study has been to document the kinds of science and literacy that predominated in the Basic Skills classroom for the better part of the year. We have tried to show how the goals of the teachers, in particular, their assumptions about what and how their students needed to learn, led to a specific interpretation of the Cheche Konnen model that effectively transformed the model into its opposite, namely, a form of science in which teacher-led lecture and demonstration, rote memorization and recitation of facts and vocabulary dominated over posing questions, developing and revising theories, planning research, and collecting, analyzing and interpreting data.

That teachers' goals, values and assumptions about teaching and learning influence instruction is not in and of itself surprising. What is striking, however, is that the investigation-based model proved robust even in the face of goals and assumptions contradictory to its aims. In the final investigation, a study of an aquatic ecosystem, the model's goals for scientific inquiry and purposeful literacy were realized in the Basic Skills classroom. The second part of this case study is concerned with describing the investigation and how it evolved, and with analyzing why it was different from the "investigations" which preceded it.

We designed the final investigation as an investigation into aquatic ecosystems. The goal is for students to begin to develop an understanding of the concept of an ecosystem through observation and analysis of the physical, chemical, and biological forces and relationships affecting aquatic life in a local pond, stream or river. As part of their investigation, students plan and carry out field studies and do studies of microscopic aquatic life. As they become familiar with micro- and macroscopic life and begin to analyze the various chemical (e.g., acid, oxygen, carbon dioxide levels) and physical properties (e.g., temperature, hydrogeologic profile) of the water, they can then begin to develop and test hypotheses about the relationships among the various factors they have identified (e.g., What happens if the temperature of the system decreases gradually? If it increases? What happens if the number of plants in the system increase?). The product of the investigation is a field guide to the local aquatic system.

In several planning meetings with the high school teachers, the ecosystem investigation was pared down from its original scope, which they found intimidating, to a project they felt they could carry out. Drawing on an earlier experience, they decided that the class would study a small pond called Black's Nook Pond that borders the city's reservoir. On an earlier trip to the pond, the students had been struck by its condition and its proximity to the city's drinking water supply. An empty oil barrel sat in the shallows along with a shopping cart, bottles and broken glass littered the shore, the water was murky and slick with oil. The students wondered how the pond came to be a dumping ground and if it posed any hazard to the water supply. The teachers thought that, by focusing the investigation on Black's Nook Pond, they could capitalize on the students' interest in it. In addition, they were able to define an authentic purpose for the Field Guide. It turned out that in the spring the pond is the site for ecology walks for elementary school children in the city. A trailer near the pond, organized by a local science teacher, is used as an on-site classroom/lab, supplying information and equipment for the children to use at the pond. But there is no guide as such to Black's Nook Pond. The teachers decided that their class would produce a Field Guide to Black's Nook that could be left at the trailer for distribution to the younger students. Thus, a goal emerged out of our joint planning that depended simultaneously on meaningful engagement in science and literacy.

During this investigation, the classroom practices we had observed earlier in the year, with their emphasis on teacher control and centralization, gave way to more student-centered, inquiry-oriented activity. For example, in planning the Field Guide, the students and teachers together formulated a set of questions about the pond they wanted to investigate, the answers to which they thought would be of interest to their readers. These questions then motivated the students' subsequent intellectual activity. The following questions are taken from a much longer list that the students generated with some help from the teachers:

1. How deep is the pond at different places?
2. Was the water in the pond cleaner in the past than now?
3. Was the pond always the same size?
4. Is it clean enough to drink?
5. Are there any fish? How do they get there?
6. Can you swim in it?
7. What kinds of birds live there?
8. What animals live there?

These questions are interesting from both a scientific and a linguistic perspective. First, in terms of scientific inquiry, they open up several possible paths for investigation, lend themselves to theory building, data collection and analysis, and to extension through new questions in the spirit of the Cheche Konnen model. For example, the first question on the pond's depth profile seems fairly straightforward. But, once the exploration begins, new complexities are soon encountered, such as the characteristics of the pond at different depths (e.g., temperature, oxygen levels, types of aquatic life), which naturally involve the students in thinking about the larger ecosystem. Secondly, while the questions are generally posed in non-theoretical terms (i.e., they are not questions seeking explanations, at least not in their original form, but questions that are more descriptive in nature), they very naturally lead to explanation and theory building, as will become evident later in this case study. To this point, the students have not yet experienced the purpose and role of theorizing in scientific inquiry. Theorizing has not therefore become a part of their discourse, at least not yet (see the analysis of Text 6 for an example of students'theorizing). Thirdly, on a linguistic level, the students' language is far more developed than the earlier transcripts would suggest. To take an example that contrasts directly with the pH lesson presented earlier, note how several of the students' questions express either explicit or implicit comparisons (or contrasts) that are far more varied both in form and function than the one comparative structure (x is higher than/lower than y) on which the pH lesson was focused. For example, the first question includes a spatially-based contrast expressed through the comparative term "different," and the second and third include temporallybased comparisons expressed differently ("cleaner in the past than now" in the second question and "Was it always the same size?" in the third).

Their questions formulated, the students met in language groups to plan their field work. The Creole-speaking group, for example, took their questions and turned them into plans and experiments. They decided on the tests and tasks they needed to perform, determined where to do the tests (on site or back in class and, if on site, at which locations), identified the kinds of data they needed to collect, and then assigned a leader for each task. At the end of the period, they had filled the blackboard with the following specifications and responsibilities:

> photographers: Rose Alta, Samson
> water samples (deep and shallow): Johnny
> fecal coliform: in class
> interview Ms. Brown (the science teacher who runs the ecology walks): Mario
>> If they clean the water
>> If they swim in the water
>> Are there chemical products in the water?
>> Can people picnic?
>
> salinity test: in class, Rose Alta
> temperature (middle, shallow): Martine
>> map, thermometer, bucket, rock, rope
>
> turbidity: ??
> perimeter: Kerline
>> bamboo, crazy glue, magnifying glass

Following this, the students formed groups of two or three to plan exactly how they would go about collecting their data. For example, the group interested in determining the perimeter designed a method for measuring the distance around the pond. They decided to take a long rope and mark it off at 10 yard intervals and then determine how many lengths around the pond was. A second group was concerned with determining the surface dimensions of the pond. They decided to measure the distance across the pond in the following way. Using a canoe, they would secure a rope on one side of the shore and then paddle to the other side. To determine the distance, they would use a rope they had marked off in yards and they would record their measurements on a map of the pond. As they hatched their plan, however, some disagreement arose as to whether they needed to measure the length of the pond at several points in order to represent accurately its surface dimensions. Some members of the group thought that, since the pond looked circular, they only needed to take one measurement. But others felt that it was not circular and that they therefore needed to take measurements at several places along the shore. In the end, they decided to take multiple measurements to determine who was right.

During these planning sessions, classroom practices were turned upside down. The students' questions motivated the investigation, validating their scientific activity in a way the earlier lessons could not. In planning their field studies, they used both their intuitive know-how and their familiarity with the pond (they had visited it earlier in the year) to devise solutions (e.g., pre-measured ropes) to the problems raised by their questions. They also began to use language in productive, purposeful ways. For example, two students developed in English data sheets for plant and animal life that were then used by many of the students at the pond. In short, the students were experiencing both knowledge and language as products of their own activity .

Finally, as evidence of the model's potential for creating a context for scientific inquiry, we include the transcript of a discussion the students had in class following the field trip. In this excerpt several of the students are reporting the results of temperature readings they took at the pond, including readings at various water depths and at different sites in and around the pond. As the results were reported, they were recorded on the board. At the point where we join the transcript, the group has established that the air temperature was 20 degrees Celsius. The class is led by the class tutor, a teaching assistant (T). T2 is the ESL teacher and T3 is the teacher we have been following throughout this case study.

TEXT 6

T: (E) Okay, so the air temperature was 20. Okay, Martine, what other results did you find?

Martine: From the side, from the side, from the side (...) in the water, it was 18.

T: Okay.

Martine: (C) The surface of the water was 15.

T: The surface where?

Martine: In the water, in the middle (...) And near, (...) near the side of the water under the trees (...), it was 15.

T: (E) Okay. These were the results Martine found. Can anybody explain why they think, what the changes were about? Why weren't they the same?

Martine: (C) Why above the water was, where when I first came the air was 20 was because it was a bit warm out and also the air (...).

13 T: (E) Okay, what Martine is saying, she's saying that when we came to the
14 pond it was pretty warm outside and that's why she thinks it was 20. What do
15 people think? Why would the water be, I don't understand why the water
16 would be different from the air.
(...)
17 Martine: (C) Because under the water, the sun doesn't hit the bottom of the
18 water.

19 Mario: (E) The sun wasn't going the bottom of the water.

20 Lorenzo: (S) The water on top is hot, because the sun hits it, but the water in the
21 bottom is (...).

21 T2: (E) Alright! Lorenzo got, just got that. See if you try to get it! The
22 temperature, can I translate for Lorenzo? He told me in Spanish. The water
23 on top of the pond is warmer than deeper down because the sun heats up the
24 water on the top.

25 T: (E) Okay, that's just what Mario was saying. Okay, great. Is that true? Did
anybody measure the water down below?

26 Student: We did.

27 T: Who did that? Roudy? Do you remember? What were your results?

28 Roudy: (C) 19 degrees.

29 T: (E) Okay, Roudy says it was 19. Everybody listen to this. Roudy and
30 Sofia took the temperature down under the water. Roudy, (C) how many feet
31 down?

32 Roudy: (C) Five.

33 T: (E) Okay. (Writing on board.) "Under the water five feet down it was
34 19 degrees." Okay, listen. Lorenzo, can you explain this?
(...)
35 Josefina: Wait a minute. The air was 20, the air was 20, and the the the the
36 water was 19? Maybe it later on it was (...).

37 T: Later on? Can you explain a little more?

38 Josefina: (...)

39 T: Hey listen to this. That's a great idea!
(...)
40 T: Listen, what Josefina said was, look, Martine took the 20 degrees when she
41 first came, right?

42 T3: Uh hun.

43 T: And then Roudy and Sofia did the temperature at about 12 o'clock or later,

right?

T2: Ohhh!

T: And she's saying maybe the sun had time to warm it up.

...

T: If we go this Wednesday, what should we do to check? What would you do, Josefina?

Josefina: Measure it (...) at two times, in the morning and at 12 o'clock.

T3: Once at this hour and once at this time? When you get there?

Josefina: Uh huh. (...) And at 12 o'clock, 12 o'clock. Most of the time at 12 o'clock the sun is hotter.

T: Okay. If you did it (...). But isn't that what we did? She did it in the morning and then they did at 12 o'clock, right? So what do you want to do differently? What's different about what you are saying? What ? Because Martine, she did it in the morning and then Roudy did it in the afternoon. How do you want to change it?

Josefina: He did it in the afternoon, I mean, you know, like the morning, sunshine. Then at 12 o'clock is more hotter.

Tutor: Okay, so what do you want to do in the morning?

Josefina: Measure the temperature.

T: Where? Which temperature?

Josefina: In the water. Outside and in the water.

T3: So you want to do in the water, in the air and the water. We're talking about both, both times? Both of them at both times? Both of them in the morning and both of them at 12?

Josefina: Yeah! (...) Two different sets!

T: Great idea. Maybe the air outside the water.

T3: You're going to do that, Josefina? Okay, Josefina gonna handle that.

T2 (to Lorenzo): (S) In the morning and the afternoon. Do you want to help her?

Lorenzo: (S) Mmhmm, but again it would be around 4 that we return?

T2: (S) Yes, we don't leave until around 4.

Lorenzo: (S) I'll stay, it doesn't matter, to take [illegible] temperature too.

76 T2: (E) Lorenzo says he'll stay until 4 o'clock and take another temperature. I
77 told him he could if he wanted to.

78 Tutor: Okay, that's a good experiment.

Several features of this transcript distinguish it from those analyzed earlier. First, the students are trying to solve a real problem, namely, the apparent contradiction between their theory that the sun doesn't warm deeper waters and their data showing that the air and deep water temperature are virtually the same. The problem is one they originally defined as of interest and for which they devised a data collection procedure. Moreover, unlike earlier classes, there is no sense here of the answer to the problem being already known, either to the teacher or to the students. Rather, the students and teachers must directly engage the phenomena of interest to determine the temperature profile of the pond and to elaborate (and then evaluate) a theory that explains it. It is, in short, the students who defined the problem in the first place and who then produced the data on which its "solution" depended.

The manner in which the students produced and then reported their data also differs from previous classes. Here data collection is distributed, with different students, or groups of students, responsible for collecting data from different parts of the pond. In earlier classes (see Text 3), all the students did the same activity at the same time. In this class, arriving at a temperature profile requires that the students share and communicate their findings with one another. Talk is thus an integral part of inquiry; to understand their data, they need to share it. And while the transcript does not contain any instances of direct student-to-student interaction, certain key moments of insight clearly depend on the sharing of distributed knowledge. The clearest example of this comes in Lines 35-36 when Josefina first realizes the discrepancy between the theory just elaborated to explain the difference between the air and water temperature (Lines 15-25) and the temperature reading taken five feet down in the pond, as reported by Roudy (Lines 27-33). Her remarks reveal that she has synthesized her fellow students' explanations and data reports and then analyzed their implications. Her "Wait a minute..." and the talk that follows it in Lines 35-36 is a particularly striking example of what Barnes (1976) has termed exploratory discourse, that is, of ideas being thought through even as they are being expressed. It is a kind of discourse typical of discussions of ideas in contrast to discourse that is typical of lessons about answers (cf. Mehan, 1979).

Not only are the students sharing data they have produced but, under the tutor's guidance, they are beginning to build theories to explain the data (e.g., why the air was warmer than the water or not, as the case may be). Indeed, several theories were put forward, not all of which are included in the section of the trans pt under discussion. One was that the air cools the water. Another was that the sun doesn't warm up the water as fast as the air. The most popular theory was that the sun doesn't reach the bottom of the water That this theory should prevail over the others (especially the one stating that the sun warms up the air faster than the water) is interesting because in fact, while valid, it fails to account for the data it is intended to explain (namely, the discrepancy between the surface temperature and the air temperature). We cannot account for its power except to conjecture that it may be one of those science "facts" the students picked up in another context or perhaps a phenomenon they have observed or experienced. Nevertheless, this theory, once stated, became pivotal to the discussion. The teacher, knowing that one group had taken the temperature at the bottom of the pond, asked them to report their results. Their data proved discrepant with the class' theory; the water five feet down was warmer than the surface and nearly as warm as the air. This "monkey wrench," as Duckworth (1986) calls evidence or ideas that raise a question about what a learner has said so that the learner reflects more deeply on his own understanding, proved to be the catalyst for Josefina's additional analysis and reflection. Her reflections led her to propose a more nuanced theory relating the changes in the water temperature to the time of day. With scaffolding from the teacher, Josefina then designed an experiment to test her theory. Thus, in this one classroom episode a model of scientific inquiry has been realized, with the students experiencing for perhaps the first time how data, theory, and experimentation interact to deepen scientific understanding. And, all of this has occurred despite the differences in first language among the main student participants.

Overall what emerges from this transcript is an altogether different interactional pattern between teachers and students than that observed in the earlier transcripts. To be sure, the teacher continues to orchestrate the interactions, but in a way that creates opportunities for discussion, exploration of data and their meaning, and questioning of ideas. She creates a context for collaborative discourse; each of her questions and each of the students' data reports and ideas contribute to a sense-making process. The poi. . .s understand the meaning of the data they have collected. If we were to use Collins' (1982) measure of uptake as an indication of collaborative discourse, the contrast between this transcript and previous ones would be striking. In this transcript, the teacher is continually incorporating the students' contributions into her questions. Indeed, the sequence of questions she asks is based entirely on the students' data and on her interest in having the students make sense of the data. In earlier classes, by contrast, questions were mostly c he comprehension checking type (e.g., Martine, do you understand?). In this class, the questions are directed toward eliciting student explanations (e.g., Can you explain a little more? What would you do, Josefina? Lorenzo, can you explain this?) and supporting students' reasoning and communication (e.g., Once at this hour and once at this time? Where? Which temperature?) rather than telling them what should be done and how it should be done. The effect is that the students actively participate in the discussion, constructing an understanding of the data they themselves have produced rather than rehearsing knowledge others have produced. It seems that the other teachers recognize this as well, expressing both their sense of engagement and discovery as the meaning of the data begins to emerge from the class' discussion (Lines 21-24, 42, 45).

We have argued in this paper that a model of collaborative scientific inquiry has the potential to create qualitatively different opportunities for both science and literacy education in language minority classrooms, thereby fulfilling a major goal of bilingual education. As evidence that good inquiry leads to productive literacy experiences and by way of introducing the final section of this case study, we include the field report[8] that Martine wrote for the Field Guide explaining the temperature findings (see Table 4):

Insert Table 4 about here

Martine's report is noteworthy for its coordination of different ways of writing science, a kind of "heteroglot" discourse through which she attempts to reconstruct the class' discussion (Bakhtin, 1981; Cazden, 1989). Opening with the list of the temperature data that the tutor wrote on the board as the students reported their results, it continues with an "objective" explanation of each temperature reading, and then, switching into a narrative voice, it "tells the story" of Josefina's insight. The text in itself is a noteworthy accomplishment, especially given the fact that no original writing at all had taken place in the class prior to this investigation.

What emerges from this report is a sense of the complexities involved in Martine's, or any student's, attempt to expropriate language for their own expressive purposes (which, as in this case, may be inextricably tied to the purposes of others such as one's teachers). In the process of trying to reconstruct her own and the class' theorizing, she makes use of several different discourses, including official classroom discourse represented in the list of temperature readings copied from the blackboard, and different forms of causal reasoning expressed in the first- and third-person. For example, somewhere in her schooling (including the classroom temperature discussion in which the students' reasons for the discrepant data were emphasized), Martine has been made aware of a discourse of explanation, largely objective and impersonal, that is appropriate to school writing tasks and perhaps to scientific discourse. But it is one she has not yet mastered, as is demonstrated by the first eight lines of her report. In Lines 1-2, for instance, the explanatory form she uses, "The air temperature was 20 C because the temperature was warm and I was in the sun," is confusing. It is as if she were saying, "I know the air temperature was warm because I was there and I felt it," a form of causal reasoning based on personal experience or evidence (Michaels & Bruce, 1989; Shiffrin, 1987). But the purpose for including this "explanation" is not really to explain so much as to establish the difference between the air and water temperature around which the classroom discussion revolved. Here Martine is trying, albeit not very effectively, to cope with the problem of contextualizing her discourse with reference to an earlier discourse, that of the classroom discussion. She then goes on to explain the other temperature readings with a theory that relies partly on observable evidence (e.g., the trees shading the water from the sun) and partly on ideas she proposes to explain the evidence (e.g., that the sun heats the air more than the water, that the deeper the water the cooler it will be because "the sun has more water to heat," and that the wind cools the water). Indeed, Martine marks these two aspects of her explanatory framework as different, when in Lines 6-8 she writes, "The water on the side under the trees was cool *too* because the sun couldn't shine on the water."

Martine's lack of control over the scientific sounding explanatory discourse form stands in marked contrast to the fluency of the end of the report, Lines 8-11, in which she invokes Josefina's reasoning to explain data she could not reconcile with her own theory. In these lines, she writes in the first person to explain that she does not know why the water five feet down was nearly as warm as the air temperature (again, the comparison is left implicit, indexed only by her inclusion of the 19° C reading). Referring to her theory, she writes, "I thought it would be cooled (sic)." She then invokes Josefina's reasoning as a possible explanation for the discrepant data, marking it as hypothetical ("Josefina thought maybe..."), subject to verification.

We include this example to illustrate the complexities involved in learning to write scientifically, and the necessary connection between that form of writing and the kinds of scientific experiences students have. As Martine's report shows, the problem of learning to write in science as much as in other disciplines is in many respects a problem in finding a voice through which one can express one's own intentions, experiences and values, a problem that Cazden (1989) has explored in a recent paper relating the work of the Soviet theorist Bakhtin (1981) on language to the developing writer's struggle. As Cazden explains, the struggle is not just to learn new ways of writing but ways of expropriating particular discourses and the values of the contexts with which they are associated to one's own purposes. Thus, for Martine as for any student, it is not simply a matter of mastering a particular explanatory form, as was emphasized in the ESL-based language exercises of earlier classes. Rather, learning to write scientifically is a matter of understanding the approach to knowledge and reasoning (and the values and assumptions) that science embodies and of finding a way to accommodate her purposes and values alongside those of the scientific and school cultures.

There are several other examples of productive literacy practices deriving from the students' scientific activity. For example, to prepare to interview Ms. Brown, two students, Mario and Romaine, collaboratively formulated the questions they wanted to ask her, with assistance from the teacher. Interestingly, question formation, like comparative formation, is a basic ESL skill. However, the literacy that emerges here is very different from the ESL lesson we saw in the pH transcript:

TEXT 7
1 T: What questions do you want to ask?

2 Mario: (in C) Does the water have chemicals in it?

3 T: Ok, let's say it in English.

4 Mario: Doe the water have chemical?

5 T: Does.

6 Mario: Does the water have chemical?

7 T: Does the water have chemicals in it?

8 Mario: Does the water have chemicals in it?
(He records this in his notebook.)

9 Romaine: Does the water have chemicals how?

10 T: How does the ...

11 Romaine: How does the water have chemicals?

12 T: Where??

13 Romaine: How does the water have chemicals in it?
(He records the question in his notebook.)

In terms of language development, which elements of this transcript are different from those of the pH transcript (Text 4)? One obvious difference is that the students have a purpose or goal in working on question formulation. Their use of English is intimately tied to the ideas they want to express and their purpose. They plan to meet with Ms. Brown and unless they can communicate their questions effectively to her, they may not get the information they want. They therefore have a stake in 'getting it right.' Secondly, rather than simply imitating a construction initiated by the teacher, the students are actually generating their own constructions. They are having to struggle with the fit between the ideas they want to express and the appropriate form(s) of their expression. This is reflected perhaps most clearly in the teacher's interaction with Romaine (lines 9-13), in which she attempts to get him to revise his poorly formed "how" question to be in the more standard "where" form (e.g., "Where do the chemicals come from?"). Romaine, however, doggedly sticks to his original question, presumably in the belief that she is taking him off track. In fact, the teacher has not in this case made sense of Romaine's purpose, as his doggedness attests. Had she pursued the "why" (as in "How come the water has chemicals in it?" or "How did it come to have chemicals in it?") route or asked him to explain a bit more what it was he wanted to know, she may have been able to negotiate a compromise with him. But it is Romaine's commitment to his own meaning that helps him resist the teacher's own interpretive framework (cf. Ulichny and Watson-Gegeo, 1989).

In a final example that takes place toward the end of the investigation, the students and teacher are collaborating on a written report of the perimeter study for the Field Guide. At the place where we enter the transcript, the teacher's expectations for the report have been discussed with the students ("Write what you saw there"), and a couple of sentences have been written:

TEXT 8
1 T: (C) Ok, but now what's important, you can't, the girls can't do the thing by
2 themselves. To do the book you have to put your heads together, you have to put
3 your heads in place. And then -

4 Mario: For the book?

5 T: When I tell you to talk about what you did at Black's Nook Pond, you have to
6 sit and think, you have to think and write about it.

7 Mario: (...)

8 T: Say it in your own speech. Now, you can write in Creole. (E) Why not?
9 (C) Right? You can write. If that's the way your ideas pass in your head.
10 (E) Ok? Then, (C) if you don't know, I can help you translate. (E) How about
11 that?

...

12 T: (C) We talked about perimeter. We did a perimeter thing. What is written
13 there? (Reads aloud in E) "We measured the perimeter." Ok. "We took a rope,
14 we marked it by yards, it was 44-" (C) What? Yards? Long? Length? Ok,
15 what was 44 yards? What was 44 yards?

16 Student: The measurement.

T: Each, the cord you used?

Johnny: Yeah.

T: It was that one that was 44, automatically. But when we did the total, what, what, estimate, what was the size of the pond? What was its perimeter?

Student: 418.

T: 418 what?

Johnny: (E) Yards.

T: Yards long. (C) In length. Ok? Do you want to do it in English or Creole?

Students: (E) In English!!

T: In English. Ok, it seems that everyone understands English well. (C) We feel like doing it in English. Ok, now I'll give you different (E) hints (C) where we should go. First, what did we do first? Who stood and measured? We did, we used what?

Johnny: A rope.

T: A rope. To do what?

Johnny: To measure.

T: Of what?

Student: The pond.

T: Ok, we used a cord to measure it. (E) Ok, what else?

Rose Alta: (C) We used a cord to take its perimeter. We, we

T: How did we know the length of the rope? Did we just take any old rope?

Kerline: We marked it.

T: What did we mark it with?

Kerline: With a thing, like the rulers. We measured it, then we marked it.
(...)
T: (E) Alright, alright. I'll be right back. (C) I gave you the second sentence, when I come back we'll do the third sentence, ok? (She leaves.)

Student: Have you got it already?

Mario (reading): "After that we, After that we," (C) what? I wasn't in that.

Johnny: (E) Stick? stick? How do you spell it?

Mario: (E) Stick? s-e-a-k-e.

Frantzia: (C) It seems that's steak. There's a steak you eat, and there's a steak that's a dirty word.

Mario: (C) Which steak? (E) Which (C) steak?

Students: Steak!

Mario: (C) You say steak is a dirty word?

Kerline: (C) Steak is not a dirty word -

Student: I understand.

Mario: They aren't written the same way!

Johnny: What?

Mario: You're saying "stink." (E) No, sorry.

Frantzia: There are two steaks, they put them the same way -

Mario: No, they aren't written the same.

Frantzia: Right, there's a stake, what I wrote there is the thing we were using to (...)

Johnny: Hey, let's go, let's go! "After that" who, who again? You went and sat, you went and stood near the tree, something like that?

Frantzia: Mmm hmmm.

Mario: (E) The rope. You make a rope?

Frantzia: I was -

Johnny: You went, I- (C) Wasn't it you and Kerline? Wasn't it you and Kerline who went?

This transcript is interesting on several counts. In lines 1-43, the teacher struggles to create a new context for collaborative discourse. Not quite knowing how to accomplish this, her discourse expresses a mixed message. She attempts to elicit the students' own thoughts and words, as in Line 8 ("Say it in your own speech") but embeds this openness in a fairly directed discourse context, as evidenced in Lines 5-6 ("When I *tell* you to talk about what you did..., you *have* to sit and think, you *have* to think and write about it.").

But, even here, the teacher is striving towards a different form of interaction than any practiced previously in the class. By directing the students to "sit and think" and to "think and write about it," she is calling their attention to a different set of criteria governing the writing task they are about to undertake. The new criteria emphasize constructing meaning from lived experience rather than merely copying others' words or transforming them grammatically as directed by the teacher. Like the tutor in the temperature transcript (Text 6), the teacher begins to elicit the students' knowledge, so that it is the students who create the narrative of their own experience. It is the meanings they intend that are the focus of the teacher's questions, even if at times it seems as if the teacher is still in control of the language (i.e., how and which ideas should be expressed). Much more than in previous lessons, the teacher is now taking the lead from the students. One result of these interactions is that each sentence in the report ends up being the work of several authors, the teacher included. Lines 29-37 provide a good example of the interaction, conducted by the teacher and ending with one student, Rose Alta, transforming the teacher's formulation of the students' contributions ("We used a cord to measure it") to make it more precise ("We used a cord to take its perimeter").

Insert Table 5 about here

Several important consequences fall out of this incipient form of collaborative discourse. One is that the report (see Table 5) is richer in detail and more accurate than the report of any single individual would have been. For example, in Lines 39-41, Kerline, who was part of the crew that developed the measurement instrument, adds to Rose Alta's description by explaining how they used rulers to mark off the units. A second consequence is that the language they use, both English and Creole, is richer than any we saw in the pH transcripts. The discussion of the distinctions among "stick," "stake," "steak," and "stink," initiated by the students would never have arisen under the lesson structure of the pH lessons, or if the students had been working independently of one another, or even perhaps if the teacher had been present. Among themselves, they effectively negotiated the meaning and spelling of homophones that are always problematic for non-native speakers. A third consequence, as exemplified in Line 37 by Rose Alta's reformulation of the teacher's summary of the students' activity and by the students' work after the teacher's departure, is that the students are beginning to exercise control over their text at several different levels. Later on in the transcript, for example, they distinguish the meaning of remember from memorize, and they work out the event structure of their field activity (i.e., what came first, second, etc). They also show a sensitivity to audience when, in the final copy of their report, they identify all the participants by name rather than through pronouns. These examples are important because they demonstrate that the students are indeed exercising control over their text, allowing it to be at once highly personal (in the sense that everyone's contribution should be recognized) and objective (in the sense that their field activity should be reported accurately). The students' sense of ownership over their text was expressed in yet another way when, despite the teacher's suggestion that work can stop while she is away, the students forge ahead (Lines 42-46). Later during the teacher's absence, Johnny steps forward to refocus the group's attention on the sentence they were constructing before the steak-stake debate (Line 61): "Hey, let's go, let's go. 'After that' who, who again? You went and sat, you went and stood near the tree. Something like that?" Their motivation and engagement was so high in fact that, at the end of the period, they asked if they could continue their writing into the next period.

The literacy manifested in this episode, in contrast to that in the earlier pH classes, is richly textured. Students grapple with word, sentence and discourse-level problems; they negotiate pronominalizations, tense, word meaning and spe'''' and event structures. They use both English and Creole to share their knowledge with one another, organize their narrative, and resolve inconsistencies and ambiguities. In t' 'nd, they produce a report which exceeds linguistically anything they have done previously. At the same time, it meets a high scientific standard, for they have produced a report which sets out in detail exactly the procedure they followed and the result they found. In short, they have provided sufficient detail for another group to replicate their study. This text, like Martine's, and the discussions on which they were based demonstrate forcefully the intimate link between collaborative inquiry in science and productive literacy in language minority classrooms.

Discussion

What accounts for the differences in classroom teaching practices we have just documented? Did the teachers value the kinds of classroom practices that resulted from the Black's Nook Pond investigation? It is to these two questions that we now turn our attention.

Changes in teaching and discourse of the kind we have observed in the Black's Nook Pond investigation derive, as Cazden (1988) has argued, from a reconceptualization of teaching and learning, not from changes in surface teaching or verbal behavior. In the earlier pH classes, for example, learning was defined in term of skills the students needed to survive in school (e.g., filling out worksheets, reading texts and answering questions, and speaking, reading, writing English). Teaching was organized so that students would practice these skills and learn some facts (about science) and rules (about English, ne process. In contrast, in the Black's Nook investigation, the teachers' classroom practices came to reflect the investigation's goals for scientific inquiry and communicative literacy.

Certain characteristics of the investigation itself may have contributed to this change, including the explicit identification of a literacy product (the Field Guide), the contextualization of the students' scientific activity in an authentic field study, and the distribution of knowledge among the students and its subsequent integration in collaborative theory building and literacy. We will have more to say about these characteristics in the final part of this report. For now, we simply want to argue that even these characteristics of an investigation will not by themselves effect a change in classroom practice. In every case, they, or the model of which they are a part, must still be interpreted by the teachers according to a set of goals, assumptions, and values about teaching and learning derived from their teaching experience.

How, then, can we explain the turnabout in the high school teachers' classroom practices? What changed? Did the teachers' goals suddenly change? Or, is it more likely that through this investigation, largely because it exploded the basis for traditional practice by placing students in control of their own learning while still maintaining certain values important to the teachers (e.g., literacy), the teachers were able to give voice to another set of goals, perhaps more idealistic than realistic in their view, which lay buried under the pressures of day-to-day schooling? We have evidence from an end of the year interview that this may indeed have been the case, and that the changes in classroom practice we observed reflected the teachers' own struggle with the nature and purposes of teaching and learning and their realization in everyday classroom practice.

Above all, through the Black's Nook investigation both teachers were able to experience in concrete terms the value of collaborative inquiry in teaching and learning. Up to this point, it was just an idea not easily realizable and, as such, it could hardly compete with established practice. As one of the teachers put it,

> (It) gave me a chance...to take students and let them come up with ideas. You go outside on a field trip and discover things and come up with stuff, let the kids discover on their own.

She continued, noting how the investigation contextualized learning:

> And they get to see the whole idea, you can see the plan there. When (they) started doing the perimeter, (they) could see that math part coming out again. You're applying, you're applying whatever to the real world."

Even more, they seemed to experience for themselves a different kind of learning, as they got involved with the students as research partners:

> I had a chance to experience it for myself and I said, 'Wow! What a nice way, learning is fun.' And nobody minds learning if they're enjoying it at the same time. And that's what I did, you know, I felt it for myself because, you know, I enjoyed the field trip.

Through the investigation they also had the opportunity to confront their fears about new approaches to teaching. One of the teachers, for example, confessed to finding the idea of doing student-initiated projects "very scary" but that with the Black's Nook experience under her belt she could imagine undertaking similar projects in the future. Here it seems a fear of the unknown pushed the teacher away from student-centered learning toward traditional practice. But, having experienced first-hand what it means to do a project and its impact on the students, fear gave way to enthusiasm. For example, the teachers commented that the investigation, and the field trip in particular, palpably changed the way in which the students interacted with one another. After the field trip,

> ...(T)here wasn't any competition anymore. It wasn't competition. Everybody wanted to help everybody else, you know, I want to help you do it, I can do it, and now I'm going to help you do it. It was really important.

This goal, apparently deeply felt, could not have been deduced from the teachers' established classroom practice; they highly value collaboration among the students but in their normal classroom practice they tend to create contexts which work against collaboration. The Black's Nook investigation helped them create contexts for collaborative inquiry and literacy of a kind they could not have imagined before.

The tension between traditional practice and inquiry-based practice was not resolved in the Black's Nook Investigation, however. In fact, there were moments when the tension was resolved in the direction of traditional practice. For example, the teachers changed the audience for the Field Guide away from the elementary school children to themselves, deciding that the Guide would take the place of a final exam and constitute one quarter of the students' grade for the year. In still another way, the goal of literacy gradually came to dominate science. This is perhaps best exemplified in a story about one student's work. The student, Roudy, conducted a fecal coliform test on a water sample from the pond. To report his results, he used the Macintosh computer application, MacPaint, to draw a representation of the sampler pad. He carefully drew the pad and its grid, and then painted in the hundreds of bacteria colonies that had grown. However, because he did not provide a written explanation, his graphic was omitted from the class' Field Guide. To the teachers' way of thinking, Roudy had failed to meet the objectives of the assignment. Viewed more broadly, however, Roudy had for perhaps the first time that year become engaged in learning. However, because the literacy goal figured so strongly in the teachers' minds, the graphic was not published, despite its scientific merit.

These examples only underscore the teachers' struggle with the nature and purposes of teaching and learning, a struggle which implicates not only the teachers' own beliefs and values about teaching and learning but also their perception of the realities of schooling and the pressures of the larger institutional context. That the Black's Nook experience had an effect is not in question. At one level, it provided both teachers and students with a different kind of learning experience. Both experienced first hand what it means to do science, to formulate questions, collect data, build and revise theories, and design and conduct experiments. In addition, they experienced literacy in its intellectual and communicative functions, both as a system for elaborating their scientific thinking and as a means for sharing ideas and knowledge. At another level, it proved a catalyst to the teachers' own thinking about teaching and learning. The interview provides a final example of the impact of the experience on the teachers' beliefs. Very near the end of the interview, they asked us if we thought a self-contained classroom where they would be free to integrate the disciplines and apportion time flexibly would be more beneficial to their students than the current arrangement. They explained that such a change would make it easier to promote the kinds of experiences found in the Black's Nook investigation, making their classroom a more productive teaching and learning environment. Having experienced the value of collaborative inquiry and communicative literacy, the teachers are now imagining ways of creating a context in which they can be more easily realized.

Lessons Learned

We have to this point focused on the contrasts not only between the two classrooms but also within the high school classroom itself. But hidden in these contrasts are some important commonalities and themes, the elaboration of which will contribute to a more fully articulated model and, more generally, to the development of strategies for enhancing teaching and learning in language minority classrooms.

The first theme to consider is that of the classroom as a social system and the implications of such a view for theory and practice in teaching and learning. By social system, we mean that the classroom is socially organized around a set of values, norms, beliefs and goals -- held by the teacher and often reflecting those of the larger institutional context (including the school, the district office and, in some cases, the community)[9] --

which regulates both social and intellectual activity in the classroom. One consequence of such a view is that the realization of an innovation in a particular classroom context will always be an interpretation, rather than an implementation, of the innovation (cf. Bruce & Rubin, in preparation; Michaels & Bruce, 1988). Indeed, we have insisted on using the term interpretation in talking about the ways in which the Cheche Konnen model was realized in different contexts because of our belief that a model, like a text, can be "read" at many different levels and be understood to mean different things, ' ·ending on the values, beliefs, norms, experience and knowledge of the interpreting ag. .n this light, understanding the ways in which a model is interpreted in different contexts is thus a crucial step in understanding how to bring about change in the contexts themselves, that is, in the ways teachers (and students) conceptualize the teaching and learning process.

In the case studies reported here, we saw the classroom social system and its effects manifested in at least two ways: first, in the ways in which teachers' goals influenced their interpretation of the innovation and, secondly, at the high school in the ways in which a change in one part of the system effected change in other parts. Certainly in the cases we have examined, the teachers' goals and attitudes towards their students and their teaching were, if not directly influenced by the larger school context, then at least reflected in it. For example, the 7th-8th grade class is housed in an alternative school that values inquiry-based education. As a K-8 school, the classrooms are self-contained, leaving the teacher with considerable flexibility in, among other things, managing time and experimenting with new approaches. Before the introduction of the innovation, therefore, a system of values, beliefs, and practices consistent with the Cheche Konnen model was already in place, although this system was more characteristic of the mainstream program than the bilingual program. But the bilingual teacher with whom we worked was expressly interested in exploring new teaching approaches which would bring her more into the "mainstream" of her colleagues' practice. Her particular interest in science as a key to developing critical inquiry in her students, combined with these aspects of the larger school culture, helped to produce an interpretation of the Cheche Konnen model that was consistent with its goals.

The high school, in contrast, is a large, urban school which offers several different programs for its students, of which the bilingual program is one. Within the bilingual program, teaching tends to follow standard practice. In the Basic Skills program this standard practice is further simplified to meet the perceived skill levels and needs of its students (cf. Cherry-Wilkinson, 1981; Collins, 1986; McDermott, 1976). This was the context into which Cheche Konnen was introduced, the effect of which was to transform the model into the very kind of school science and literacy against which it had been defined: traditional classroom practices organized around worksheets and ESL exercises for the transmission of factual and rule-based knowledge about both science and language.

But, as we discovered, even apparently strongly held values can mask a deep conflict over the purposes of teaching and learning, a conflict which we suspect is felt by many teachers as they try to come to terms with the realities of schooling. The Black's Nook investigation in many crucial ways challenged the teachers' assumptions and seemed to bring to the surface a conflict in their own beliefs about teaching and learning at the same time that it created an opportunity for a new kind of science and literacy learning. The changes in classroom practice that resulted, however, would not have taken place had the teachers' not valued the shift in goals represented in the investigation. Had they not valued those goals, they would have produced a very different interpretation of the investigation. Indeed, as the case study showed, their interpretation was not always internally consistent precisely because of the conflict they felt. This was expressed perhaps most clearly when they transformed the Field Guide from an authentic written product for others' use to a product written to be evaluated by the teacher.

The lesson, then, is that teachers' long-established practices will be difficult to change as long as they continue to be functional in the classroom context (Cazden, 1988). To change teachers' classroom practices requires a change in the culture of teaching and learning itself; the value of alternative practices must be demonstrated and experienced in contexts that are specifically designed to promote such practices over traditional ones. This will be true in cases like the 7th-8th grade class where the teacher valued certain goals but did not know how to accomplish them and in cases like the high school where the teachers found themselves in conflict over the true purposes of education and teaching.

A second major theme to emerge from the two case studies is that knowledge, or what students learn, is inextricably tied to the ways in which it is learned, that is, to the "context, activity, and culture" (Brown, Collins & Duguid, 1989) in which it is developed and used. In both the Water Taste Test and the Black's Nook Pond investigation, we saw how the students' understanding and use of the conceptual tools of science to pose questions, formulate theories, and design and conduct studies to evaluate their theories evolved through direct engagement in authentic scientific activity. In essential ways, this activity helped structure the students' cognition, consistent with recent theories of situated learning (Collins, Brown & Duguid, 1989). In both classrooms, for example, the dilemmas and issues they met, and which gave rise in many instances to the most intellectually demanding challenges (e.g., determining with some degree of certainty whether the class' taste test results were reliable; constructing an explanation that would resolve the discrepancy between the class' temperature theory and the data they collected), grew directly out of the activity in which they were engaged. And to resolve these problems, the students drew on both their intuitive knowledge and the activity context itself. For example, as the high school class tried to work out the apparent contradiction in the temperature data, one student made explicit use of the context (namely, that Martine had taken her readings early in the morning) as the basis for elaborating a new theory and a study to evaluate it.

Thus, by situating learning in authentic scientific activity, the Black's Nook investigation created the possibility for a radical change in fundamental aspects of the teaching-learning process. Most notably, perhaps, it dictated a shift away from the teacher as the possessor and dispenser of knowledge to the student as producer and sense-maker. In particular, through their questions and explorations, the students sought knowledge that neither they nor the teachers already possessed. This was equally true in the 7th-8th grade class, in which the question driving the investigation sought knowledge that challenged existing but unexamined beliefs. Thus, in both classrooms, students actively produced knowledge in interaction with the world, through direct contact with the phenomena they were studying (cf. Duckworth, 1986). This marks a significant departure from the usual classroom practice of rehearsing knowledge already known by the teacher for the teacher, as was common in the high school class prior to the Black's Nook investigation.

One effect of this restructuring of teacher and student roles was that the purposes of talk and writing in the classroom also changed. They shifted away from transmitting the teacher's meaning system and evaluating the students' mastery of it to students' actually constructing the meaning of data they had produced or experiences they had had and evaluating their own sense-making (e.g., evaluating the adequacy of their theories in relation to the data they collected and designing new studies to test their claims). In the process (to harken back to our first theme), a change in one part of the classroom social system, the practice of science, produced changes in another part, the practice of literacy.

As the purposes of talk and writing shifted, so did the way in which they were accomplished, through social interaction, both between teacher and students and among peers. In particular, discussions replaced virtual teacher monologues as the teachers sought ways to bring together knowledge that was distributed throughout the group. Through these discussions, distributed knowledge[10] was shared, evaluated and extended, and theories were formulated, challenged and revised. In the context of the Black's Nook investigation, the students now had something to say and think about; the teachers' job was to elicit this knowledge and discover what sense the students were making of it rather than what sense they were supposed to be making, as dictated by the teacher, the text or the curriculum. As Duckworth (1986) has written,

> 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. (p. 489)

Not insignificantly, with knowledge distributed throughout the learning context, the teachers were also interested in the sense that was constructed since, in effect, they knew less or as much as, but never more, than the students. Through collaborative inquiry, therefore, they, too, had the opportunity to explore the bounds of their knowledge as well as that of their students, as co-investigators.

But the social construction of knowledge was not accomplished only through teacher-student interactions. In discussions, the students also showed that they could help one another make sense of their data and their experience, as they theorized in the context of data they had produced. Martine's report, in which she incorporates Josefina's theory to explain data she could not reconcile on her own, stands as one example of how knowledge is socially constructed and, more specifically, how the exchange and modification of ideas through group discussion can influence and enrich student learning (cf. Brown & Palincsar, in press; Inagaki & Hatano, 1983). The students' collaborative writing experience stands as another example of the way in which social negotiation mediates understanding, in writing as much as in science.

In addition to demonstrating the situated nature of learning (Brown, Collins & Duguid, 1989), the experience of the Black's Nook investigation also teaches some important lessons about teacher education, lessons which must be incorporated explicitly into the Cheche Konnen model if it is to prove robust in different classroom contexts. First, in order to understand what collaborative inquiry in science means, teachers must experience it directly, whether in collaboration with other teachers or with their students as happened in both classrooms in this study. Through this experience, they develop not only a sense of authentic scientific practice but also a conceptual understanding of a particular domain from which they can then shape new investigations. Secondly, and growing out of the first point, teachers need to become curriculum builders, who can adapt existing materials to the purposes of collaborative inquiry and who can take students' questions and help shape them into investigations. In the 7th-8th grade class, the Water Taste Test arose directly from the students' interest in their school water, extending the water quality investigations they were doing into an unexpected quarter. At the high school, the teachers worked with the researchers to carve a more manageable investigation out of a larger, more ambitious Aquatic Ecosystems investigation developed by the researchers. Finally, teachers need to have the means for assessing in an ongoing fashion their own teaching and their students' learning. As the case studies reveal, longstanding classroom practices are often resistant to change. To bring about and sustain changes in such practices, teachers need to be able to analyze critically the assumptions, expectations, values and understandings that underlie their talk and actions and the talk and actions of their students; they must, in effect, become researchers who work at understanding their own ways of talking, thinking and acting as well as those of their students, ideally in school and in the community (cf. Heath, 1983). This is particularly important in the education of language minority students whose community and home-based literacies may be in conflict with the school-based literacies they are expected to acquire (e.g., ways of talking, reading, and writing in science, mathematics, etc.).

Finally, this work suggests a further generalization of our second theme -- that robust learning, whether in a discipline such as science or in language, grows out of purposeful engagement with complex, ill-defined problems rather than mastery of oversimplified and decontextualized facts and procedures -- to bilingual education in particular. In bilingual education, it seems there is an even stronger impulse toward oversimplification and decontextualization than in mainstream education programs, owing to the concern with developing students' English skills. But these pedagogical strategies are based on faulty assumptions about the students' communicative and reasoning abilities and results in the setting of artificial limits on what they can achieve. The two case studies reported here argue that not only are language minority students capable of meeting the intellectual challenge posed by authentic scientific activity but that this activity itself is capable of resolving the tension between disciplinary learning and language development that has frustrated bilingual education since its inception.

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Author Notes

We gratefully acknowledge the teachers, students, principals and administrators who have made this work possible and Courtney Cazden who commented on an earlier presentation of the case studies.

The work reported here was supported under the Innovative Approaches Research Program funded by the Office of Bilingual Education and Minority Language Affairs of the U.S. Department of Education and administered by Development Associates, Inc. under USDE Contract No. 300-87-0131. The opinions expressed are those of the authors and do not necessarily reflect those of the funding agency.

Footnotes

1 A good example of how "stories" develop comes from the paleontologist Stephen Jay Gould's (1989) book, "Wonderful Life: The Burgess Shale and the Nature of History." In it he shows how scientific decisions in the later to be revised interpretation of the Burgess Shale fossils were conditioned by the assumptions and beliefs of the discipline and the culture dominant at the time, namely, the view of evolution as progress.

2 We also interviewed each of the students in September and June. The interviews probed various aspects of the students' scientific reasoning, their knowledge of aquatic ecosystems, and their attitudes toward science. Results of this analysis will be reported in a separate paper.

3 It is important to point out that there are at least two readings of the teacher's meaning when she says that she wants to "replace" the students' folk beliefs with more scientifically grounded explanations. One is that the teacher wants to extinguish the students' culture in favor of another. This is not the meaning the teacher intends. The other reading is that far from extinguishing their culture, she wants to help the students adapt to what she views as a different cognitive environment from that to which they are accustomed, namely, one which demands that they analyze and evaluate problems critically and use, in her words, a "scholarly approach" in solving them. In Haiti, learning tends to be passive, with rote memorization and recitation the rule. For this teacher, the responsibility of transitional bilingual education programs is twofold: to improve students' English language skills <u>and</u> to help them acquire Western, scholarly ways of thought.

4 All transcriptions in this case study are translations from Creole.

5 Inaudible or unintelligible speech is indicated by (...) in the transcripts.

6 There are many possible reasons for this. For example, we may not have communicated the project's goals effectively. Other elements of the school context (e.g. pressures from other teachers in the Basic Skills program) or of the teachers' beliefs about what their students were capable of doing may have influenced the teachers to do things in particular ways. The teachers themselves may not have felt comfortable enough with the science content to experiment with new ways of teaching. In fact, all of these influences likely had an effect. Indeed, goals are often the expression of a complex web of influences and values, and that is why we have chosen to focus on them in our analysis.

7 Indeed, this sort of hypothesizing would lead to exactly the kind of learning that was absent in the transcript just examined. Through it, students would begin to discuss the meaning of pH and to formulate an informal notion of the pH scale. For example, they could taste the various liquids and then categorize them qualitatively (e.g. very acidic, mildly acidic, not acidic, etc.). In the process, they would likely disagree about their categorizations which would lead to a discussion of precision and the need for a more finely tuned instrument than taste. Indeed, activities like this were suggested in a guide we prepared for the teachers.

8 Martine's report covers only the first field trip and the subsequent class discussion. Unfortunately, due to bureaucratic constraints, the class was not allowed to return to the pond, so Josefina's experiment was never carried out. Martine wrote the report with the help of the class tutor. She composed mostly in Creole but at times in English, with the tutor translating as directly as possible into English.

9 We have in this report largely focused our contrastive analysis on the classroom level, in particular, on the ways in which teachers' goals affected their interpretation of the innovation. But teachers' goals are just one part of a much larger system of institutional barriers and supports that includes administrators, teachers, parents, district curriculum and assessment standards, and so forth. Teachers' goals and attitudes may be as much conditioned by those of the larger system as they are by deeply held personal values.

10 Knowledge, it should be noted, was necessarily distributed as a consequence of the *complexity* of the students' scientific activity.

Table 1

	(Floor I think I most prefer) Etaj m di m pi pito	(place I drink from most often) Kote m bwe pi souvan	(I choose) M chwazi: A	B	C	Nor
(First) premye	I		III	卌 II	I	I
(Second) dezyem	III					
(Third) twazyem	卌 III 8	卌 卌	3rd	1st	2nd	
			ki dlo	elev yo		
			chwazi	apre	tes la	

(which water the students chose after the test)

[illegible]

pH. Measuring Acids and Bases

[illegible]

Name ____ ____________________________ Date ________________

We measure [illegible] acidic or basic a substance is with a number called pH. The pH numbers are from 0 to 14.

A substance with a pH less than 7 is called an acid.
A substance with a pH more than 7 is called a base.
A substance with a pH of 7 is neutral. It is neither an acid or a base.

A pH of 0 means very acidic. From pH 7 to 0, the substance is more acidic.

Orange juice has a pH of 4 and lemon juice has a pH of 2.

Which is more acidic? ____________________________________

How do you know? ____

A pH of 14 means very basic. From pH 7 to 14, the substance is more basic.

Ammonia has a pH of 11 and baking soda has a pH of 8.

Which is more basic? _____________________________________

How do you know? ____

[illegible] **pH. Measuring Acids and Bases**

[illegible]

Name ________________________________ Date ________________

We measure how *acidic* or *basic* a substance is with a number called *pH*. The pH numbers are from 0 to 14.

A substance with a pH less than 7 is called an *acid*.
A substance with a pH more than 7 is called a *base*.
A substance with a pH of 7 is *neutral*. It is neither an acid or a base.

A pH of 0 means very acidic. From pH 7 to 0, the substance is more acidic.
Orange juice has a pH of 4 and lemon juice has a pH of 2.
Which is more acidic? ________________________________
How do you know? ________________________________

A pH of 14 means very basic. From pH 7 to 14, the substance is more basic.
Ammonia has a pH of 11 and baking soda has a pH of 8.
Which is more basic? ________________________________
How do you know? ________________________________

Table 4

Martine

The air temperature was 20 degrees C.
The water near the side was 18 C.
Under the surface of the water in the middle
of the pond was 15 C.
On the side of the water under the trees, it was 15 C.
Under the water 5 ft down the temperature was 19 C.

The air temperature was 20 C because the temperature was warm and I was in the sun.

The water was cooler than the air because the sun was shining more on the air than on the water the wind blew on the water and cooled it. Under the surface of the water in the middle of the pond was cooler because the middle was deeper than on the side so the sun had more water to heat. The water on the side under the trees was cool too because the sun couldn't shine on the water. I don't know why the water was 19 c. 5 ft down I thought it would be cooled. Josefina thought maybe it was because I took the temperature in the morning and they took the temperature in the after noon when it was warmer.

Table 5

we measure the perimeter of the pond. we used a rope. it was 44 yards long. we used a yard stick to measure the rope. Franzia and Merline looked for a wooden stick that we needed also. Franzia helded the rope beside a big tree, to remember where we started to measure the perimeter of the pond. At the end of the rope we put the wooden stick. After that, Franzia left us to go on the canoe to measure the length of the pond. Johnny took Franzia place. we started to measure again at the wooden stick. That's the way we took the perimeter by repeating the measurement with the rope 9 times and half. At the end we found that pond was approximately 412 yards long.

Rose alta and Johnny.

Figure Captions

Figure 1. Kenia's graph of fountain preferences before the taste test.

Figure 2. Andrew's alternative graph of fountain preferences before the taste test.

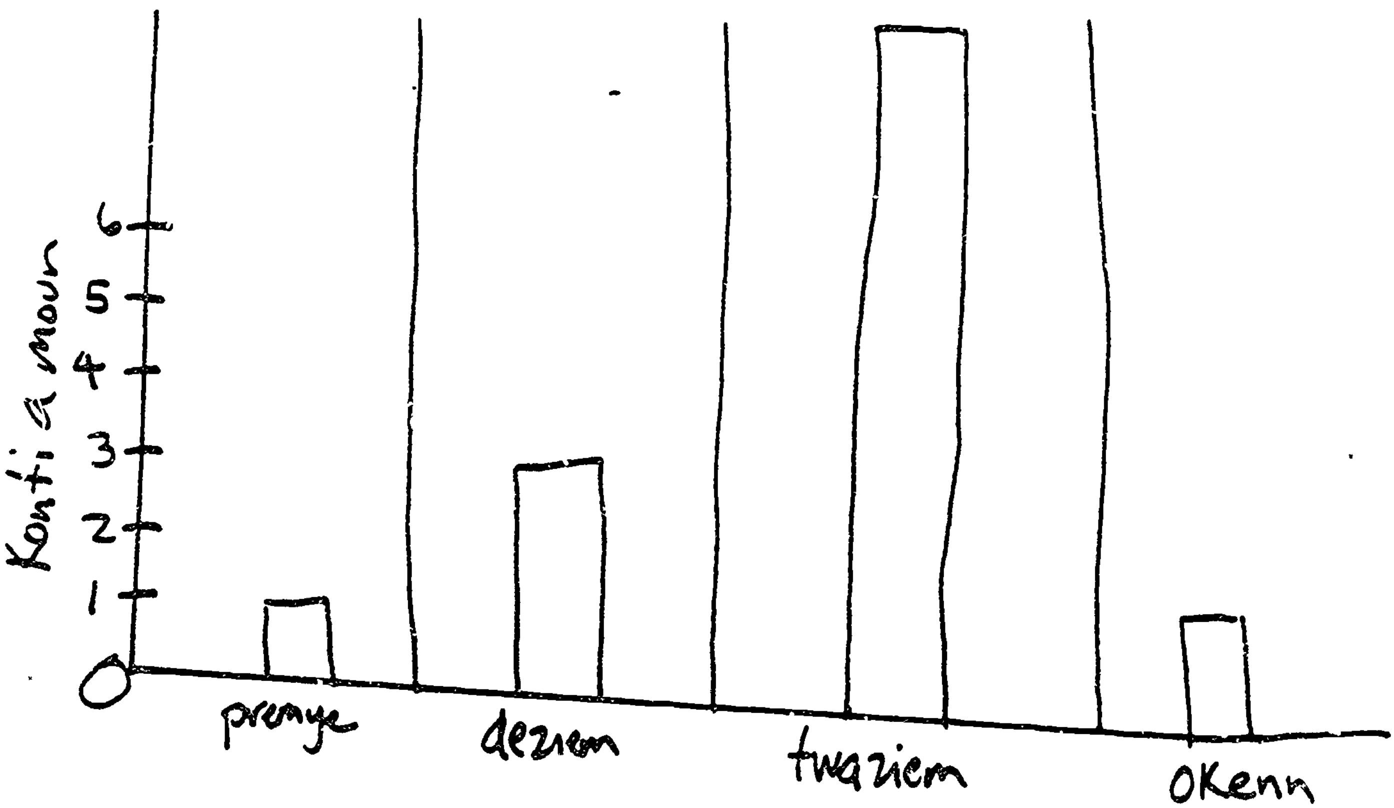

Figure 1. Kenia's graph.