DOCUMENT RESUME

ED 343 .34 FL 020 202

AUTHOR	Warren, Beth; Rosebery, Ann S.
TITLE	Cheche Konnen: Collaborative Scientific Inquiry in Language Minority Classrooms. Handbook for Teachers and Planners from the Innovative Approaches Research Project. Second Edition.
INSTITUTION	Development Associates, Inc., Arlington, Va.; Technical Education Research Center, Cambridge, Mass.
SPONS AGENCY	Office of Bilingual Education and Minority Languages Affairs (ED), Washington, DC.
PUB DATE	Sep 91
CONTRACT	300-87-0131
NOTE	56p.
PUB TYPE	Guides - Non-Classroom Use (055) -- Reports - Descriptive (141)
EDRS PRICE	MF01/PC03 Plus Postage.
DESCRIPTORS	Classroom Techniques; Communication Skills; Computer Literacy; Elementary Education; *English (Second Language); Guidelines; *Haitian Creole; *Instructional Innovation; Interdisciplinary Approach; Intervention; Literacy; *Mathematics Instruction; Minority Groups; Models; Public Schools; *Science Instruction; Secondary Education
IDENTIFIERS	*Cheche Konnen; Innovative Approaches Research Project; *Language Minorities

ABSTRACT

An innovative instructional intervention model is presented that represents a promising approach to the education of language minority students. One of the four handbooks produced to document and disseminate the findings of the Innovative Approaches Research Project (IARP), this handbook describes the IARP model for providing science and mathematics instruction. School personnel, parents, and educational planners can use it to assess the appropriateness of the intervention for their schools, and teachers can use it for explicit advice on implementing the model. The Cheche Konnen ("search for knowledge" in Haitian Creole) model uses a collaborative inquiry approach to science in which students pose their own questions, plan and implement research, collect and analyze data, build and revise theories, draw conclusions, and make decisions. The goal is for students to develop scientific ways of thinking, talking, and acting. The Cheche Konnen approach is interdisciplinary in its use of literacy skills and the use of mathematics and computers as tools for explaining and communicating scientific findings. The model was tested with Creole-speaking Haitian students in two urban eastern schools, a public elementary school and a public high school. This handbook describes the implementation of the model and examples of the scientific inquiry method that were conducted and assessed in the field test with seventh and eighth grade students. Illustrations, student work samples, margin notes, which summarize the contents of each page, lists of contacts and materials available, and a bibliography are included. (LB)

Cheche Konnen

Collaborative Scientific Inquiry in Language Minority Classrooms

A Handbook for Teachers and Planners

Beth Warren and Ann S. Rosebery
Principal Investigators
Bolt Beranek and Newman, Inc.

Faith Conant, Research Associate
Josiane Hudicourt-Barnes, Teacher

Charlene Rivera
IARP Director
Development Associates, Inc.

September 1991
Second Edition

A Handbook for Teachers and Planners from the Innovative Approaches Research Project

Cheche Konnen

Collaborative Scientific Inquiry in Language Minority Classrooms

A Handbook for Teachers and Planners
from the Innovative Approaches Research Project

Beth Warren, Co-principal Investigator
Ann S. Rosebery, Co-principal Investigator
Faith Conant, Research Associate
Josiane Hudicourt-Barnes, Teacher

Handbook for Teachers and Planners
Cheche Konnen: Collaborative Scientific Inquiry in Language Minority Classrooms

Technical Education Research Center
2067 Massachusetts Avenue
Cambridge, Massachusetts 02140

Development Associates, Inc.
1730 North Lynn Street
Arlington, Virginia 22209-2023
telephone 703 276-0677

September 1991

This project was supported by the Office of Bilingual Education and Minority Languages Affairs of the United States Department of Education under contract number 300-87-0131. The views contained in this handbook do not necessarily reflect the positions or policies of the U.S. Department of Education.

Contents

PREFACE

This handbook describes an innovative instructional/intervention model that represents a promising approach to the education of language minority students. It is one of four handbooks produced to document and disseminate the findings of the Innovative Approaches Research Project (IARP).

The IARP evolved from concerns about the status of education for language minority students. By the middle of the 1980's, four critical areas were identified: literacy instruction, science/math instruction, dropout prevention, and the instruction of exceptional students. Improvements in those areas were needed to enhance the educational opportunities of language minority students. To gather more timely information and provide models which offered the promise of real solutions, the U.S. Department of Education, Office of Bilingual Education and Minority Language Affairs (OBEMLA), funded the Innovative Approaches Research Project in September 1987.

The structure of the IARP represents an innovation in the management of federally funded education research. OBEMLA chose Development Associates, Inc. of Arlington, Virginia, to manage and direct the overall IARP effort. Development Associates, in turn, issued a problem statement and solicited collaborators to conduct research and demonstration projects that addressed issues in the four critical areas. Numerous educational research organizations and investigators responded with their ideas and IARP staff convened peer-review panels to select the most appropriate responses. The projects selected by the peer-review panels were funded by Development Associates and implemented in local schools from 1988 to 1990.

The research collaborators selected to conduct the IARP research and demonstration projects were first asked to identify promising approaches to the education of language minority students in the specific topic areas. Second, they were asked to test the effectiveness of those approaches in actual school settings. Third, they were asked to document the implementation procedures and the outcomes of the approach. Finally, they were asked to collaborate with IARP staff in preparing handbooks and technical materials. The IARP staff is presently disseminating the results of the project and beginning a process of replicating the models.

This handbook, *Cheche Konnen: Collaborative Scientific Inquiry in Language Minority Classrooms*, provides information about the IARP innovative model for providing science and mathematics instruction, which was implemented in an urban school district in the eastern part of the United States. School personnel, parents and educational planners may use this handbook to assess the appropriateness of the intervention for their schools. Also, teachers may look to the handbook for explicit advice on implementing the model. Therefore, the handbook provides many details about effective strategies and required resources for replicating the model. It also gives clear examples of the instructional strategies used on a day-to-day basis to make classroom teaching effective.

We have also sought ways to make this handbook easy to use. The main text was prepared by the research collaborators and represents their findings. The document is structured so that an interested reader may grasp the essential aspects of the model by reading the overview and major features section. Practitioners might wish to pay special attention to the "What Do I Do?" section. In the concluding sections, the research collaborators note the results that schools might expect if the project were replicated and they also provide the names of resource people. In addition, the researchers have provided detailed bibliographical citations within the text and in a supplementary bibliography at the end of the volume.

Complementing the collaborators' text, the IARP Development Associates staff has written the margin notes to help guide readers through the material. These margin notes are designed to orient readers throughout the text and provide a narrative thread for readers who are perusing this material for the first time.

❖❖❖❖

Several groups of people are responsible for the accomplishments of the IARP. First, I would like to thank the OBEMLA staff for their vision in designing the IARP and for the opportunity to implement the project. Without the technical expertise and support of OBEMLA staff, including the Director of OBEMLA, Rita Esquivel; the Director of Research for OBEMLA, Carmen Simich-Dudgeon; the IARP Project Officer, Alex Stein; as well as the Grants and Contracts Officers, Jean Milazzo and Alice Williams, the project would never have fully enjoyed the success it does today. Credit must also be given to Warren Simmons, the first IARP project officer, who conceived this highly innovative project.

Next, I would like to extend appreciation to the IARP Development Associates staff and project associates—Peter Davis, President; Malcolm Young, Corporate Officer-In-Charge; and Paul Hopstock and Annette Zehler, Associate Project Directors. Bonnie Bucaro, Research Assistant to the IARP, has provided critical assistance and support. Richard Ottman, Teresa Crumpler, Lisa Bonaparte, Loretta Johnston, Allan Kellum, Howard Fleischman, and Mark Morgan supplied expertise at critical times during the project. A special thanks to Richard Duran, Professor at the University of California, Santa Barbara; Walter Secada, Director of the MRC at the University of Wisconsin, Madison; and Joel Gomez, Director of the National Clearinghouse for Bilingual Education, who provided sharp insights, expert advice, and guidance. Jose Mestre, Professor of Physics & Astronomy at the University of Massachusetts, was a continuing reviewer for the project and also deserves recognition. Richard Moss provided valuable editorial assistance and graphic design ideas for the IARP products.

Finally, I would like to thank the Cheche Konnen collaborators: Beth Warren; Ann Rosebery; and Faith Conant. You made science exciting for many students and teachers. I would also like to acknowledge the dedication of the school principal Leonard Solo and the teachers, Josiane Hudicourt-Barnes, Jennie Galloway, Claudie Jean-Baptiste, Karen Rudgis, Marly Mitchell, and Isabel Prime. The students, parents, community members, and the extended support staff were enthusiastic participants in this worthwhile project, and I would like to thank them as well.

Charlene Rivera
Development Associates, Inc.
Arlington, Virginia
September 1991

INTRODUCTION

Margin Notes

The Need for Innovative Approaches

The proportion of school-age children in the United States who come from non-English language backgrounds has increased substantially over the past several years. As a result, a large number of students enter our nation's schools each year with limited oral and written communication skills in English. The provision of effective instruction to these language minority students is one of the most critical challenges confronting today's schools (Lara and Hoffman, 1990).

This challenge comes at a time when schools are in the midst of instructional reform aimed at meeting educational demands imposed by the social, economic, and technological changes that have occurred in the decade of the eighties. Competition from abroad and the occupations created by new advanced technologies have created demands for higher achievement in science and math. Structural shifts in the economy, along with technological advances in computer and electronic automation, have altered the nature of the job market and increased the importance of literacy in the workplace. The implications of these changes are that many of those without adequate skills will have difficulty obtaining and keeping jobs in the years ahead (U.S. Equal Employment Opportunity Commission, 1986).

The substantial increase in the number of language minority students in our schools has occurred at a time when schools are facing demands for higher standards in areas such as literacy, mathematics, and science. It is therefore critically important to ensure that language minority students receive instruction that will be effective in assisting them to reach high levels of achievement in these areas.

Schools today thus face enormous pressures to raise standards and to change the objectives of schooling in ways which incorporate activities and content designed to develop oral and written communication skills and critical thinking skills. Evidence suggests that reforms introduced in the 1980's to meet these ends are beginning to have an impact. However, there is rising concern that the school reform movement may serve to widen the already substantial gap between the achievement of majority students and those from minority groups, unless special steps are taken (McPartland and Slavin, 1990). In response to this concern, a renewed emphasis is being placed on strengthening programs serving language minority students whose academic progress is jeopardized by conflicts between the language and culture of the schools and those found in their homes and communities.

The Response: Innovative Approaches Research Project

In responding to the need to strengthen instructional programs for language minority students, the U.S. Department of Education identified four critical target areas: literacy instruction, science/mathematics instruction, dropout prevention, and the instruction of exceptional students. It contracted Development Associates, Inc. of Arlington, Virginia to direct a comprehensive project, known as the Innovative Approaches Research Project (IARP), which would address each one of the critical areas through four separate research and demonstration projects. The four projects were:

- Community Knowledge and Classroom Practice: Combining Resources for Literacy Instruction;
- Cheche Konnen: Collaborative Scientific Inquiry in Language Minority Classrooms;
- Partners for Valued Youth: Dropout Prevention Strategies for At-Risk Language Minority Students;

Margin Notes

For each IARP model the processes and procedures involved in carrying out the instructional innovation were carefully documented to ensure that the models could be reinterpreted in other classroom settings with majority and language minority students alike.

- AIM for the BESt:
  Assessment and Intervention Model for the Bilingual Exceptional Student.

Although each of these projects was implemented in a specific school setting and with a specific language minority population, it was expected that an individual model and/or its component parts would be generalizable to other settings and applicable to language minority and non-language minority students in other communities. In order to help ensure that the results of the IARP projects would be replicable, both the research and the demonstration aspects of each project were carefully documented, focusing on how the insights gained might be used to implement the innovative models in other settings and with different populations.

The IARP research and demonstration projects were significant in that not only was each project based on a firm theoretical framework but the implementation of each project was a collaborative effort involving researchers, administrators, and teachers who worked together in the classrooms and schools and who jointly shaped the refinements in the processes and procedures of the individual models. For this reason, the research and demonstration phase of the projects was particularly informative and led to important insights about effective instructional approaches for language minority students.

Interestingly, in reviewing the findings of all four IARP models, it became clear that despite the diversity of approaches and differences in focal areas, there was considerable commonality among the models. The common themes that became evident concern the importance of the organization of schooling, the value of teaching and learning approaches that restructure the traditional teacher/student relationships, and the importance of presenting language minority students with challenging content that is relevant to their experience and needs. Each model, as a specific example of these common themes, presents challenging ideas about more effective ways to structure schooling and the teaching/learning process.

This handbook presents Cheche Konnen: Collaborative Scientific Inquiry in Language Minority Classrooms. Below, as an introduction to the handbook, we provide a brief outline of the Cheche Konnen model, followed by an overview of the common themes and approaches in the IARP models. In the discussion, we refer to aspects of the Cheche Konnen model to exemplify some of the general themes and approaches being described.

Cheche Konnen's Approach to Science and Mathematics Instruction

Cheche Konnen takes an approach that responds to the new demands for greater technological sophistication and increased critical thinking and problem-solving skills imposed by recent societal shifts. In Cheche Konnen, students actively construct scientific understandings through collaborative, interdisciplinary investigations of problems that the students themselves identify.

Using the "investigation-based" approach, students work as scientists: they formulate hypotheses; they work together to collect, analyze, and interpret data; they prepare reports on their work. In this way, students begin to see science as a tool for answering important questions rather than as an inventory of "already-discovered facts". The approach is interdisciplinary in its emphasis on the use of literacy skills and the use of mathematics and computers as tools for explaining and communicating scientific findings.

Cheche Konnen thus challenges students by creating educational contexts in which students deal with more complex content and take on greater responsibility for their own learning. This is in contrast with traditional approaches to science instruction for language minority students in which adaptations of the regular curriculum frequently result in a dilution of the material and a greater emphasis on lower-level skills. The success of Cheche Konnen suggests that the investigation-based approach is appropriate for all students, including students who bring into the classroom differing language and cultural backgrounds, different knowledge of math and science concepts, and differing levels of proficiency in English and in their native languages.

Margin Notes

Common Themes and Approaches in IARP Models

In reviewing the findings of all four IARP models, the common themes reflected the importance of the organization of schooling, the value of instructional approaches and interventions that restructure the traditional teacher/student relationships, and the need to present challenging and meaningful instructional content to language minority students. The common themes identified in the four models involve emphases on:

- the need for restructuring schooling to open up communication within the school community;
- the value of using participatory and cooperative teaching and learning approaches; and,
- the importance of providing instructional content that is challenging and that is culturally and personally relevant to students.

The implementation of the four IARP models has provided insight to how effective change takes place in schools. The elements that made the IARP models effective included restructuring traditional teacher/student relationships, using interactive teaching approaches, having high expectations for students, and providing content that is both challenging and relevant.

To persons familiar with the educational literature, these kinds of emphases are not all new; they reflect several issues and approaches that have received much discussion. However, the importance of the IARP models lies in the fact that program elements representing a specific and unique integration of these emphases were found within each of the models. Each model, as a specific example of these common themes, presents challenging ideas about more effective ways to structure schooling and the teaching/learning process. It is in these aspects that the IARP has fulfilled its goal of identifying innovations that can be used to successfully address the needs of language minority students. Thus, the common themes outlined below offer an important introduction and context to the handbook description of the Cheche Konnen model.

Restructuring Schooling

Throughout the implementation of the IARP research and demonstration projects, typical boundaries that existed within schools were crossed or broken down. The resulting increase in communication and collaboration among all school staff and in particular among those staff serving language minority students was an important factor in the success of the models. These innovations involved the restructuring of the schooling process. With regard to classroom practices in particular, the restructuring of schooling relates to:

- the relationship between the process of collaboration and innovative practices; and,
- the relationship between innovative practices in the classroom and traditional instructional policies.

And, with regard to school organization, the restructuring of the schooling process involved changes in:

Margin Notes

- the relationship among schools and among classrooms within a school; and,
- the relationship between schools and communities.

The restructuring of these relationships carried out within the models led to significant changes in classrooms and ultimately to the changes observed in students' attitudes and performance.

Relationship Between the Process of Collaboration and Innovative Practices

All four of the IARP models included a new, expanded role for teachers in which teachers worked together to develop and to in fact define the specific application of the innovative model in their classrooms. That is, while typically teachers have been trained to function very independently, in the IARP models teachers collaborated with each other and with the researchers to work through and test ideas for working with their students.

An important component of the innovative practices was the collaborative work of the teachers. Their collaboration provided mutual support and assistance, and provided a forum for discussing new ideas for their classrooms.

The process of collaboration was actually an integral part of the innovative practices demonstrated by the models and played a significant part in their success. Collaboration gave teachers a forum in which they could voice their ideas for innovation and find mutual support and assistance in working out these ideas; the approach both made teachers themselves more receptive to change and created a strong base for change within the school.

In Cheche Konnen, teachers collaborated together and with researchers in developing the inquiry approach to science and math instruction. Even though the teachers began without strong confidence in their ability to teach science, working together with each other and with the researchers allowed each teacher to benefit from the knowledge and perspectives of the others and to make her own contribution. In the process, the teachers began to understand that the inquiry approach was one in which they could also work and develop their understanding, parallel to the process in which their students were becoming engaged. The collaborative process led the teachers to feel more confident in instructing their students and gave them opportunities for sharing ideas for making the science sessions even more effective vehicles for learning.

Relationship Between Innovation and Traditional Instructional Policies

The IARP models also broke down walls constructed around teachers by school policies or common practices and by traditional training. Educators working on the IARP models were challenged to rethink what teaching is about, how they approach students, what role the established curriculum should have, and how school policies affect the teaching/learning process.

For each IARP model there was initially some resistance to the changes in common practices that were required in implementing the new model. However, in each case, the results and student outcomes of the innovative practices justified the changes and convinced others of the value of the new instructional approaches or interventions.

In implementing Cheche Konnen, teachers interpreted and reinvented the model to address the needs of their students and to satisfy their own goals. Their interpretations resulted in a shift in the level and nature of instruction, as well as the restructuring of class time for investigations. Students were given increased responsibility for their learning and time to follow through on their questions, discoveries, and experiments. Such flexibility made possible the successful completion of complex scientific investigations and the resultant gains in student scientific understanding.

Margin Notes

Relationship Among Schools and Classrooms

The IARP models defied traditional ways of thinking about schools and classrooms. Teachers from different schools seldom interact with one another, and within schools it is generally the case that teachers work in isolation. Within the IARP models, these traditional structures were changed.

The IARP models created linkages among classrooms and schools; within classrooms, linkages across subject area boundaries created dynamic contexts for learning.

The multidisciplinary approach in Cheche Konnen broke down strict divisions between disciplines and restructured the usual school day in which blocks of time are devoted to learning particular disciplines. In the Cheche Konnen model, science, language, and mathematics were viewed as complementary aspects of learning to think. The research collaborators noted that: "The approach emphasizes not only the reasoning processes and conceptual knowledge that fuel the activities of science and mathematics...but also the social and linguistic processes that mediate them" (Rosebery, Warren, and Conant, 1989). The result of the approach was the creation of a context for learning in which science, math, and language were intertwined.

Relationship Between Schools and Communities

In general, few genuine attempts have been made to build a bridge between the culture of schools and the culture of the communities from which students come (Heath, 1983; MIT, 1990). IARP instructional models recognize that schools must have a link to the real world in order to be meaningful to students.

The IARP models were innovative in building links between classrooms and communities, and in using students' prior knowledge as a basis for the development of new learning.

This is a fundamental principle in all of the IARP models. The Cheche Konnen model exemplified this theme in a number of ways.

In Cheche Konnen the beliefs of students are taken as starting points for inquiry; their often extensive prior knowledge is shared and discussed and provides the basis for the formulation of hypotheses and for experimentation. It is important to note that Cheche Konnen does not seek to replace student beliefs, whether cultural or personal, with a "correct" answer. Rather, students are encouraged to consider their beliefs from different perspectives and to think critically about their assumptions. One Haitian teacher often challenged the students to think about how they could find out whether their belief about the water fountain were "true" (i.e., was it "true" that the third floor fountain water tasted better to them than the first floor water? What could the results of a blind taste test tell them about their belief?). In the context of Cheche Konnen, and in science generally, what is considered "true" is open ground for exploration, argument, and reconsideration. Cheche Konnen scientific investigations are meant to give students the opportunity to hypothesize, experiment, and argue; to develop and acquire new perspectives and strategies for making sense of the world around them. An example of the acquisition of such new strategies is evident in the student interview discussed on p. 24.

Because the students' own questions and beliefs serve as the bases of investigations, the researchers noted that:

> ...students will be working toward goals that are meaningful to them and optimally 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 the community (Warren, Rosebery, & Conant, 1989, p.5).

Margin Notes

The instructional approaches of the IARP models emphasized active participation of students in learning tasks and cooperation among students in carrying out these tasks.

Thus, the science investigations served to give students a better understanding of their world while at the same time giving them an understanding of science and scientific ways of thinking and knowing.

Teaching and Learning Approaches in the IARP

The IARP interventions also shared similar approaches to teaching and learning. While the exact mix of approaches and the specific forms they took in implementation were different for each model, all four of the IARP models made use of a combination of participatory teaching and cooperative learning approaches. That is, in each case the research collaborators arrived at the same conclusions: First, effective teaching involves teachers and students in meaningful learning tasks that are relevant to the individual student's experience. Second, effective learning activities involve students in cooperative work where they assume responsibility for their own learning.

Participatory Teaching/Learning

A key feature of instruction found in each of the four IARP research and demonstration projects was an approach to teaching that encourages students to actively participate in learning activities. For the language minority student, participatory learning is important because it (1) acknowledges that individuals learn in many different ways; (2) allows students to frequently practice and use their developing English and other language skills; (3) provides teachers with important feedback on student problems and achievement; (4) allows students to integrate their unique cultural and personal perspectives; and (5) generally improves student motivation and attention.

In Cheche Konnen, student-defined and student-initiated activities became the center of instruction. The emphasis for the student was on defining what they already knew, identifying what were meaningful extensions of that knowledge, and finding ways in which students could most effectively gain new knowledge and skills.

Cooperative Learning

Cooperative learning is a method of instruction that is student-centered and that creates interdependence among students, involving them in face-to-face interaction while maintaining individual accountability. In classrooms where cooperative learning is utilized, students work jointly to accomplish an academic task, solve problems, or resolve issues. Cooperative learning can take a number of forms, such as peer tutoring, group projects, class presentations, etc. Cooperative learning within the IARP research and demonstration projects reflected the belief that teachers and students have considerable resources to offer each other and that those resources should be effectively used in the teaching/learning process.

Cooperative learning has been shown to be an effective pedagogical tool and is particularly appropriate for language minority students, many of whom come from cultural groups where cooperative approaches are highly valued (Cochran, 1989; Jacob & Mattson, 1987; Kagan, 1986; Solis, 1988). The advantages for language minority students are: (1) high levels of interaction and communication are required, stimulating students to productively use cognitive and oral English language skills; (2) students with heterogenous knowledge and skill levels help one another to meet lesson goals; (3) student self-confidence and self-esteem can be enhanced through individual contributions and through achievement of group goals; and (4) individual and group relations in the classroom may be improved.

Margin Notes

In Cheche Konnen, students collaboratively designed and carried out investigations to examine empirically based problems in the local school and community environment. The problem of identifying the "best" water fountains in the school involved groups of students in various experiments that were generated as the result of peer interaction. Groups of students determined the different tasks to be accomplished, assigned responsibility for these tasks to each other, and in this way produced surveys, analyses, and written reports of their investigations.

The Content of Instruction for Language Minority Students

In the IARP models, the instructional approaches used helped to refine the content of instruction. First, the implementation of the innovative approaches required shifts in the curriculum toward more challenging levels of work. And second, the innovations also included a focus on making instructional content more relevant to the cultural background and personal experiences of students.

Challenging Level of Instructional Content

Frequently, the content of instruction provided to language minority students is reductionist and instructional activities are focused on lower-order skills such as rote learning. However, lack of full proficiency in English does not and should not limit students to learning only content that requires lower-order thinking skills. The example of the IARP models showed that when teachers have high expectations and present academic tasks that are complex and challenging, students become more engaged in and challenged by their learning, and instruction begins to tap their true potential for learning.

Language minority students perform well when teacher expectations are high and they are presented with challenging and complex tasks.

Presenting challenging content to students is a reflection of high expectations held regarding their abilities. Within the Cheche Konnen model, the previous culture of low expectations for at-risk students was replaced by high expectations through the responsibilities given to the students in carrying out scientific investigations and through the level of work required to carry them out. As the students began to report on the results of their work, other students and teachers not participating in the model began to develop more positive attitudes about the abilities of the language minority students involved in Cheche Konnen. In addition, the other students and teachers became interested in the potential of the model for their own classrooms.

Culturally Relevant Learning

A second common characteristic of instructional content within the IARP models was that instruction was consistently grounded in the personal and cultural experiences of students. Some of the benefits of such culturally relevant instruction are (Kagan, 1986; Tikunoff et al., 1981; Cazden & Legget, 1981):

- it works from the basis of existing knowledge, making the acquisition and retention of new knowledge and skills easier;
- it improves self-confidence and self-esteem of students by emphasizing existing knowledge and skills;
- it increases the likelihood of applying school-taught knowledge and skills at home and in the communities represented by the students; and,

Margin Notes

- it exposes students to values, information, and experiences about other cultural and language groups.

While traditionally there have been obstacles to integrating personally and culturally relevant teaching styles and materials into the classroom (e.g., lack of materials, lack of information, impracticality when several cultural groups are present in a class, etc.), the IARP models provided strategies for overcoming some of these by emphasizing the important interrelationships among home, school, and community.

Cheche Konnen approached the issue of culturally and personally relevant learning in several ways. First, for example, students were encouraged to define a science problem for investigation which had meaning to them, such as trying to discover the reasons for the perceived difference in taste between water from the various fountains in their schools. Also, the researchers in Cheche Konnen acknowledged the "home culture" explanations and observations of phenomena and examined these as part of the process of learning about scientific method, and in gaining an understanding of the explicit nature of scientific discourse.

Summary

The outcomes of the two years of research and demonstration of the IARP models are significant in two ways. First, each innovation was demonstrated to have a positive impact on students and, importantly, on the classrooms and schools involved as well. Thus, each of the IARP models provides a specific example of effective instruction/intervention for use in schools with language minority students.

Second, the findings of the IARP models taken together argue for important general changes in schools and classrooms in order to make schooling more effective. These are changes that involve the structure and organization of the school, the teacher/student relationship and instructional approaches used in the classroom, and the type of instructional content presented to students.

This handbook outlines the implementation of Cheche Konnen, the IARP model focused on science and math instruction. The handbook offers guidance for those who are interested in implementing the model and outlines the types of outcomes that might be expected from the use of the model. In addition, the last section of the handbook provides further sources of information on the model and its findings.

The Problem and the Challenge

Margin Notes

We know from the seemingly endless number of educational 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).

The researchers cite literature about science education. Their point is that schools aren't teaching science very well in general and are doing especially poorly with language minority students.

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 National Assessment of Educational Progress (NAEP) data show, school science is a mix of lecture, demonstration, memorization and assessment (Mullis & Jenkins, 1988). Students do not 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 activity as it is practiced by professional scientists.

Rote memorization is not a good way to learn science; rather, students should learn how to think scientifically by doing science.

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 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 instill negative attitudes and conceptions about science, especially in language minority students, many of whom come to school without a strong sense of what science 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 to student ratios, and availability of materials and technologies (Office of Technology Assessment, 1987). Secondly, teachers of language minority students are typically trained in language, not science and mathematics. 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). This problem is aggravated by the lack of usable 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). Language minority students' community- or home-based literacies come into conflict with the school-based literacies they are expected to acquire.

Researchers note four factors which impede science instruction for language minority students: first, limited resources in school communities serving language minority students; second, few bilingual teachers are trained in science; third, limited expectations for the language minority students; and fourth, conflicts in values between the school and the language community.

To address these problems, we have developed and field tested a collaborative inquiry approach to science for language minority students called Cheche Konnen ("search for knowledge" in Haitian Creole). The fundamental idea behind this approach is to involve language minority students in "doing science" in ways that practicing scientists do, through conducting authentic scientific investigations. What this means in practice is that students are encouraged to pose their <u>own</u> questions, collaboratively plan and implement research to explore those questions, collect, analyze and interpret data, build and revise theories, draw conclusions, and make decisions based on their research. The goal of the project is for students to develop scientific ways of thinking, talking and acting.

The research group worked with Creole-speaking Haitian students in two urban eastern schools. The project emphasizes a "collaborative inquiry" approach to teaching and learning.

From this initial characterization of the project, it should be clear that we are putting forward an innovation that is very far from the kinds of science learning found in schools. In most school science, lectures predominate over investigations and textbook-based learning of facts and procedures predominates over

Margin Notes

In Cheche Konnen, students construct scientific knowledge—the teacher sets the tone and establishes an environment where students can ask questions, theorize, and explore. It is an environment in which students experience science as a dynamic process of sense-making.

posing questions and interpreting data. In school science, a fixed body of knowledge is contained in texts and communicated by teachers to students. Meanings are given, they are explained, and occasionally they are absorbed. They are not constructed through active theorizing, experimentation and observation as in authentic scientific practice. In Cheche Konnen, in contrast, students actively *construct* scientific understandings through collaborative, interdisciplinary inquiry. The role of the teacher in this process is to guide the students' sense-making and to create an environment in which hypothesizing, exploration, theorizing, experimentation and multiple viewpoints are valued and encouraged. In short, it is an environment in which students experience science as a dynamic process of sense-making rather than as the static accumulation of already established fact.

The Cheche Konnen Approach

The researchers explain how the Cheche Konnen approach is influenced by a sociocultural perspective on "scientific literacy."

The Cheche Konnen approach is influenced by a sociocultural perspective on what it means to be, and become, scientifically literate. In Cheche Konnen, scientific literacy is conceptualized as a discourse which, as Gee (1989) explains it, is a way "...of using language, of thinking, and of acting that identify one as a member of a social group." Our view of science as a discourse suggests that when students become scientifically literate, they are not simply acquiring facts and procedures. Rather, they are learning a scientific way of thinking and knowing with its own beliefs and values, its shared history, and even its shared mythologies (Latour, 1987; Latour & Woolgar, 1986; Longino, 1990). From this perspective, the primary goal of Cheche Konnen is to teach students how to talk, think and act as scientists.

How is this accomplished? To become scientifically literate, students must become fluent in, or *enculturated* into, the ways of making sense that are characteristic of scientific communities. Cheche Konnen attempts to do this by placing *scientific investigations* at the heart of science education.

The teacher is the key to scientific inquiry: if she believes science is dynamic, there will be a spirit of inquiry in the classroom. The learning environment is critical.

The teacher is key to this process. As Schoenfeld (in press) has argued with respect to mathematics, teachers' beliefs about the nature of the scientific enterprise (for example, how scientific knowledge is constructed) determine the kind of classroom environment they create. That environment, in turn, influences students' beliefs about the nature of science and the kinds of scientific understandings they develop. If the teacher believes, for example, that scientific knowledge is fixed and predetermined, then classroom interactions will reflect that belief. As a result, students will not understand that science is a discipline in which they can explore the bounds of their knowledge, pose questions, or put forward and evaluate conjectures. If, on the other hand, the teacher believes that scientific knowledge is dynamic, then it becomes possible to create a classroom environment in which students understand that they are responsible for asking and exploring questions, and for doing research to investigate the value of those questions. The critical point here is that for students to gain a sense of what science is and then to be able to use science in meaningful ways, their experience with science must reflect the ways it is actually practiced. For the teacher, this means creating a community of authentic scientific practice in the classroom.

The authors stress the importance of a classroom environment in which the teacher does not impart theories and scientific facts; instead, she encourages students to act and think like scientists.

We stress the importance of the classroom as a community of practice (Lave, in preparation) because it moves us away from the traditional notion of education as instruction and towards a notion of education as socialization or enculturation (Resnick, 1989; Schoenfeld, in press). The view of scientific literacy—and with it, scientific practice—we are putting forward argues for less instruction of skills and strategies and more enculturation—that is, students appropriating scientific values, knowledge and perspectives through direct, albeit assisted, participation in the work of a scientific community. In Cheche Konnen, this is accomplished through collaborative scientific inquiry.

In the next few pages, we outline the Cheche Konnen collaborative inquiry approach. We discuss the value of collaborative practices in science, the role of inquiry in guiding students' investigations, and the interdisciplinary nature of scientific activity, that is, the roles that mathematics and literacy play in science. We also point out some of the ways in which a collaborative inquiry approach is different from standard classroom practice.

Margin Notes

The Model

The emphasis in Cheche Konnen on collaborative inquiry—students defining and collaboratively investigating the problems they wish to study—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. It is through interaction with others—teachers, students, scientists or other experts—that scientific knowledge is built by the individual, not in isolation from the larger community. In view of this, the typical school practice of having students work individually at their desks does not support scientific sense-making. Rather, scientific practice in schools must become collaborative in nature, both between students and between students and teachers.

The theoretical underpinning for the model is discussed. Vygotsky writes in Mind in Society that students don't acquire knowledge passively; rather they construct it through interaction with others. In school this means that teachers and students collaborate to produce meaningful scientific knowledge.

The value of collaborative inquiry is that it provides direct cognitive and social support for the efforts of individual students. 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 sharing of intellectual responsibility is particularly effective for language minority students because the language demands of complex tasks can overwhelm and even mask their true abilities and understanding. In addition, collaborative inquiry creates powerful contexts for constructing scientific meanings, for example, when students use data to debate the explanatory power of rival theories. 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 (Barnes & Todd, 1977; Brown & Palincsar, in press; Hatano, 1981; Inagaki & Hatano, 1983).

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. The Water Taste Test investigation, described in "What Do I Do?", exemplifies this process. In its first stage, students conducted a blind taste test to confirm their belief that one water fountain in the school, the one they always drank from, had "better" water than the other fountains. When the results of their test showed that most of them actually preferred the water from the "worst" fountain in the school, the students were shocked and suspicious of their results. This suspicion motivated them to conduct a second test with a larger sample of students. When their second test confirmed the results of the first, the students wanted to find out why one water fountain was preferred over the others. To answer this, they analyzed the school's water fountains for differences in bacteria, salinity, and temperature.

To get started students—not teachers—need to define a problem. They pose questions, the investigation of which gives rise to new questions.

The stages of the Water Taste Test clearly show how the results of one experiment can lead to new questions that, in turn, spawn additional research. The course of the Water Taste Test could not have been predicted in advance; it grew directly out of the students' beliefs and questions. This is how inquiry proceeds: the investigation of one question motivates additional explorations,

Margin Notes

initially unforeseen. For this reason, in Cheche Konnen, there is not a set curriculum; investigations evolve through the joint activity of students and teacher.

By pursuing their questions, students work towards goals that are meaningful to them and, optimally, to the larger community (which can encompass the classroom, the school, or the outside community). In this way, through their own activity, students begin to bridge the gap that separates the school culture from the culture of the home and community (Heath, 1983). In addition, by planning and implementing investigations, students learn how to confront the kinds of ill-defined problems that arise from authentic scientific activity. They learn that there are alternative investigative paths to a problem and that many different questions can be pursued at any given point. And, importantly, they learn that there is not necessarily one solution or answer to a given problem.

Students also learn that there is not necessarily a single right answer or solution to a problem.

Finally, collaborative inquiry is interdisciplinary. Mathematics and language serve as essential tools of scientific inquiry. This stands in sharp contrast to traditional schooling in which science is separated from math and the role of language in each is hardly acknowledged. Mathematics mediates students' scientific sense-making primarily through data collection and analysis activities (e.g., measurement, statistics, graphical analysis and representation). In one field test classroom in which the students investigated the health of a local pond, mathematics was used in diverse ways. The students created tools for measuring the depth, length and width of the pond; they tackled unit conversion (e.g., feet to yard; inches to feet) to standardize their measurements; and they learned about exponents to understand the pH scale. In other field test classrooms, students explored relationships in their data using different graphical representations, including bar graphs and scatterplots.

The approach is interdisciplinary. Students use mathematics and language as they carry out scientific research.

Language (talk, reading and writing) plays an equally crucial, mediating role in collaborative inquiry as a system both for thinking and talking scientifically and for communicating and sharing ideas. By conceptualizing science as a discourse, we are emphasizing the pluralistic nature of literacy, that is, that we all acquire many different literacies over the course of a lifetime. When acquiring new literacies, students do not simply learn the form of a language and then apply that form to generate meanings. Rather, they learn to use language in specific ways and situations to accomplish particular purposes, such as to answer questions in school, to tell stories at the dinner table, to play with peers, and so forth (Cazden, John & Hymes, 1972; Gee, 1989; Heath, 1983). This is the heart of the perspective on language that underlies the Cheche Konnen approach. Through authentic scientific activity, students expand their linguistic repertoire, in both first and second languages, to encompass the discourse of science. In the field test, for example, students acquired the language of theorizing as they tried to make sense of data they collected at a local pond. They produced a field guide to the pond, with descriptions of the various forms of aquatic life they found there. They also constructed, wrote and practiced how to phrase questions in English in order to interview a chemist at the local water treatment plant.

The researchers argue that science is a discourse—a way of speaking and thinking. By doing science, the students learn to speak and think as a scientist does: asking questions, developing hypotheses, and interpreting evidence.

Using the Cheche Konnen approach, students expand their communication skills and develop written products associated with their scientific inquiry—e.g., field guides, reports, etc. For language minority students, Cheche Konnen provides real-life opportunities to use language to solve problems.

The importance of an interdisciplinary approach for language minority students cannot be overstated. It involves them directly in the kinds of purposeful, communicative interactions that promote genuine language use, which we believe are the most productive contexts for language acquisition. It also creates opportunities for students to use the languages of science and mathematics in ways that society at large requires: not just to read textbooks, but to write reports, argue theories, develop evidence, and solve meaningful problems.

In sum, Cheche Konnen is forging links between learning science and doing science, and among science, mathematics and literacy. This is in large part what makes it a powerful model for language minority students. Central to the approach is that students formulate questions about phenomena that interest them; build and criticize theories; collect data; evaluate hypotheses througt experimentation, observation and measurement; analyze and interpret data; and communicate their findings. Literacy—in the form of purposeful talk, reading and writing—and mathematics mediate each of these scientific efforts.

Margin Notes

Overview of Field Test

Cheche Konnen was field tested in two public schools in a large city in eastern Massachusetts. The field test ran for two years in collaboration with teachers and administrators of an elementary school (grades K–8) and a high school. Approximately 140 students and six teachers participated. The project represented a partnership between teachers and researchers in which both parties contributed significantly to its success.

The field test city is ethnically and economically diverse. Currently the public schools serve approximately 8,000 students, 1,000 of whom receive bilingual education. More than one quarter of the students are from homes in which English is not spoken. As with most large East Coast cities, the language minority population is heterogeneous, including more than 12 different language groups.

Cheche Konnen was tested in both an elementary (K–8) school and a high school. The elementary school classrooms included Haitian students while the high school classroom included a broad range of language groups.

Public Elementary School

The elementary school houses the city's Haitian Creole bilingual program and a mainstream alternative program. It has approximately 400 students in Kindergarten through eighth grade, 30% of whom are in the bilingual program. It is an "alternative" school, offering in its mainstream program education that is more open-ended and inquiry-based than that found in traditional elementary schools. Six classes participated in the field test. In the first year, a combined 7–8 grade participated; in the second year, four additional classes joined the 7–8 grade, for a total of five classes. These classes included two Kindergartens (one bilingual and one mainstream), a combined 1–2, and a combined 3–4. In total, approximately 115 students and four teachers from the elementary school participated in the field test.

Students got science instruction in either English or Creole as appropriate.

Public High School

The high school serves 2,700 students, approximately 270 of whom are in the Bilingual Program. Students in the Bilingual Program are from nine different cultural and linguistic groups. In many cases, bilingual education mirrors the mainstream program. In addition, the Bilingual Program offers a Basic Skills class for those students whose low academic and literacy skills prevent them from participating in the regular bilingual program. The Basic Skills class participated in the first year of the Cheche Konnen field test.

The Basic Skills class is for the academically weakest students, those who are at greatest risk for dropping out or for school failure. Six language groups were represented in the class: Haitian Creole, Spanish, Portuguese, Amharic, Tigrinya, and Cape Verdean Creole. The class participants included approximately 25 students and two teachers.

The six field test classrooms represented a range of educational contexts for language minority students. The 7–8 grade class was a bilingual class where science was taught primarily in the students' native language, Haitian Creole. The Basic Skills class at the high school and the combined 1–2 and combined 3–4 classes at the elementary school were ESL classes where English was the principal language of instruction. The Kindergartens represented yet a third context. A mainstream Kindergarten collaborated with a Haitian bilingual

Margin Notes

Kindergarten on a year-long investigation. Thus, both English and Creole were used in science, depending on which language was appropriate for a given group of students.

For the most part, all of the language minority students in the field test functioned below grade level. Academic proficiency ranged from those students who were approximately two years below grade level to those who could not read or write in either their native language or English and had only rudimentary mathematics skills. In fact, some had never attended school before. Most had no previous exposure to science.

The teachers didn't have any science training prior to the project.

In all classes, science was taught by a classroom teacher who had no science training. Prior to Cheche Konnen, science had been taught sporadically, if at all, in these classes.

Field Test Investigations

During the field test, students conducted five investigations in four topics areas: water quality, weather, plant growth and human physiology. Each of the investigations is described briefly below.

Students in the 7–8 grade and the high school Basic Skills class conducted water quality studies during the first year of the field test. Although the investigations were on the same topic, they were different in character and content because they were motivated by students' questions. The combined 7–8 grade conducted an investigation into the quality of water in their school. This study is described in detail in "What Do I Do?"

This section describes the activities in the various classrooms. The high school class studied the ecology of a local pond. The 7–8 grade students asked why the water tasted better at a particular fountain in their school. The Water Taste Test is elaborated on page 13.

The Basic Skills class conducted an investigation into the ecology of a local pond. In their study, students analyzed the physical, chemical, and biological properties of a local pond. For example, they measured the depth, length and width of the pond. They created a profile of the air and water temperatures. They analyzed the pH, turbidity, and salinity of the water. And they catalogued the plant and animal life they observed, including in-class examination of water samples for microscopic life. In the end, they produced a field guide to the pond. (See Figures 1 & 2 in the Appendix for sample entries from the Field Guide.)

The second year of field testing produced investigations on three topics: weather, plant growth, and human physiology. The bilingual and mainstream kindergartens collaborated on a year-long investigation of local weather. Students investigated and collected data on clouds, wind, precipitation, and temperature to explore their influence on local weather patterns. In their studies, they collected daily data on wind speed, wind direction, precipitation, air temperature, and cloud formation and movement. They also developed a taxonomy of cloud types. To conclude their study, the students studied relationships among the variables, looking for patterns in their weather.

The combined 1–2 and 3–4 classes conducted an investigation of factors affecting plant growth. They examined the effects of water and light on the germination of seeds and subsequent plant growth. For example, they tested the effects of natural sunlight, artificial lamplight, and no light on the growth of mung beans. Three times a week, they recorded plant growth, focusing on stem height, color, and number of leaves. Data were recorded in individual logs as well as on a class growth chart. The classes also participated in the NASA Space Tomatoes study, where they investigated differences in the growth of tomato plants germinated from seeds that spent ten years in space and seeds that spent ten years on earth.

In the second year of the field test, a new group of 7–8 graders conducted a study of human physiology. They investigated the effects of salt on weight, height, and physical condition, including blood pressure. They were motivated to conduct this study because members of their families, and one or two of the students themselves, had high blood pressure and were on salt restricted diets.

Using a questionnaire they developed to measure salt, the students collected data at the school science fair to investigate, among other things, whether people who eat a lot of salt are out of shape (see Figure 3, p. 34, for a copy of the 7–8 graders salt questionnaire). Although their salt questionnaire data were problematic, students found several interesting relationships to explore among the other data they collected.

In the third year, the 7–8 graders investigated sound. Students first built simple instruments using bottles, water, cans, rubber bands, and donated guitar strings to explore relationships in sound. A drum maker in the community helped them build their own authentic Haitian wooden drums for use in a school play. Having constructed the drums, they continued their exploration of sound in small groups, using their drums as a focus for their experimentation. One group documented the construction of the drums and translated their report into English. Another group analyzed traditional Haitian drum music, developing their own notations to express pitch, duration of sound, and how different sounds are produced on the drum. Another group, using software that allowed them to see and print sound waves of different types of drum stroke, developed and wrote explanations of the shape of the wave forms of sounds produced by their drums, focusing in particular on volume and pitch. The results of the projects were shared among the groups and a display of the work was exhibited at the entrance to the school play.

In summary, the investigations treated a variety of topics, unified by their emphasis on scientific inquiry but each unique in its content and implementation. The high school class spent much of its time and energy on literacy work in the context of writing the field guide, while the 7–8 graders' salt study focused more on experimental design. In the Kindergarten study, the most interesting hypotheses came <u>after</u> students had collected a significant amount of data. In this case, the data served as a catalyst for ideas and discussions. In the Water Taste Test, students began their inquiry with a question and other questions arose as their study unfolded.

Margin Notes

Each classroom project was unique but the key to each was inquiry. Thus the literacy activities, too, differed among the classes: some age groups spent more time in writing; other age groups spent more time in thinking through experimental design.

Implementation of Model

In order for Cheche Konnen to succeed, teachers and administrators must be truly committed to collaborative scientific inquiry. This is no small task; it means changing notions about what language minority students can achieve and how they should learn. Not surprisingly, implementing an innovation of this scale takes time, money, and dedication on the part of all concerned. In this section, we outline the kinds of challenges that face a school interested in adopting Cheche Konnen. We also discuss the kinds of resources that are needed to help meet those challenges.

Environment for Success

The success of an innovation like Cheche Konnen is determined in large part by the extent to which it is supported by the school environment. This includes the efforts of the school administration as well as of the bilingual and mainstream staff.

Supportive Administration

The importance of a supportive administration to the success of any innovation cannot be overstated. Cheche Konnen must have administrative support on a variety of levels, from day-to-day details to more global policy issues. For

Margin Notes

Collaborative inquiry requires support from the administration. Principals may be asked to support more "open" classrooms, flexible schedules, and stipends for teachers. This type of learning also requires extra preparation time.

The researchers suggest forming a community of inquiry. At the center are bilingual teachers—preferably working in pairs or small groups. Other participants might include the science curriculum specialist, as well as scientists from the local community.

example, it is important that the principal encourage collaborative forms of learning, for example, that students be allowed to move freely about the classroom and the school as they conduct scientific investigations. While this may seem like a small point, the attitude it represents about how learning should happen and what constitutes a "good classroom" runs contrary to the prevailing culture of most schools. At another level, the administration can arrange teachers' schedules to allow those who are collaborating on an investigation to have joint preparatory periods. At yet a third level, principals can support teachers' efforts with stipends or honoraria. In short, the administration must work to establish a school-wide environment that values collaborative inquiry.

Community of Inquiry

In collaborative inquiry, students are encouraged to ask and investigate their own research questions, to design and carry out experiments, to distribute work among themselves in order to solve complex problems, and in general to work more independently than in traditional models of school. So that teachers may better understand and support collaborative inquiry in their classrooms, it is important that they establish a community of individuals interested in nurturing scientific inquiry in their school. Ideally, this group will constitute a critical mass of interest in the innovation that will spread throughout the bilingual program and perhaps to the school at large. The community should be comprised of teachers from the bilingual staff, support staff (e.g., science specialists or curriculum developers), administrators, teachers from the mainstream program, and scientists from the local community.

The bilingual teachers, of course, will be at the heart of the community. We found in our field test that teachers are most comfortable when they can collaborate in pairs or small groups on an investigation, as happened in the Kindergarten weather investigation. In this way, they have colleagues with whom to generate ideas, share activities, and talk about what worked and what did not.

Support staff, such as a science specialist or curriculum developer, can be invaluable members of the community. Bilingual staff will need the support and guidance of such personnel as they struggle to put a science program into place. For example, in one of our field test classrooms, a science specialist collaborated with an ESL teacher to design an introductory unit on plants that led to an investigation of plant growth. Dedicating a portion of a staff developer's time to the innovation greatly increases the chances of success.

Other teachers in the school can also be valuable members of the inquiry community. For example, in our field test, ESL and resource room teachers supported scientific investigations by helping students compose texts (e.g., letters and reports) in English. In each of these cases, students' learning was enriched and broadened by the support and cooperation of the classroom teacher's colleagues.

Finally, it is important that local scientists, engineers, or museum staff be brought into the school community. Their participation in investigations and their interaction with teachers and with students can be especially rewarding, particularly for teachers who feel less than expert on a given investigation topic. In the field test, we found that local experts are pleased to be asked to contribute to students' investigations. For the water quality investigations, for example, the chemist at the city's water treatment plant hosted groups of students on tours through the plant and later offered to corroborate their bacteria counts of school water. The school nurse turned out to be a valuable colleague for the bilingual teacher whose class conducted the salt investigation. The availability of such experts helps the teacher see herself as a conduit between students and

Margin Notes

appropriate knowledge sources rather than as the repository of scientific knowledge per se.

Role of Technology

While Cheche Konnen does not require any special technology (e.g., computers, calculators) in order to be implemented, available technology can be used in support of students' scientific investigations, just as it is used by professional scientists. Students in the field test classrooms invariably responded with enthusiasm to technologies that were introduced to support their work; such technologies have included relatively inexpensive items such as pH paper, thermometers, anemometers, and sound meters, to more costly items such as computers. In designing an investigation, teachers or students may wish to call a local scientist for suggestions of appropriate and inexpensive technologies which would be useful for their purposes. When using computers, software should be chosen with the goal of providing students the opportunity to examine their own data in creative ways. Cheche Konnen students have used statistical software, word processors, and Microcomputer Based Labs Sound software which allows students to produce sound waves in real time by using a specially designed microphone hooked up to an Apple 2e. It is important that students experience technology as a means to help answer or explore their questions rather than as a self-contained end in itself.

Resources Required: Time and Money

Collaborative inquiry places extra demands on the teaching staff and on the school.

Implementing an inquiry-based science program for language minority students is a developmental process. Teachers must be allowed to gradually change the way they think about teaching and learning. And they must be allowed to develop the confidence and expertise necessary to organize collaborative scientific inquiry. All of this, of course, takes time and money.[1]

Teachers must be given time in which they can learn, plan, and reflect on how their classrooms are evolving. They need time to learn the subject matter that is the topic of students' investigations. They need time to meet with one another to plan investigations and to discuss inquiry activities. They need time to prepare for class. Preparing for collaborative inquiry takes longer than preparing for textbook or worksheet-based classes because, in inquiry, the focus is on thinking and learning as well as on subject matter. Finally, teachers need time to learn what it means to do collaborative inquiry. (The issue of teacher enhancement is discussed in more detail in Barriers and Solutions.)

Regular meetings of teachers, support personnel, administrators, and scientists should be held. Teachers vary in the degree to which they want such support. In our field test, some teachers wanted to attend a weekly two-hour meeting, while others only attended a meeting on a monthly basis. These meetings serve as a forum for discussing issues of classroom management, scientific content and activity, equipment, and ways of interacting with the larger school or city community. For example, it is here that teachers get input into how to engage students in authentic scientific inquiry on an ongoing basis.

Teachers can learn the methods of scientific inquiry through teacher study groups. By collaboratively studying water, for example, and measuring, observing, discussing results, taking data, developing questions and hypotheses, teachers prepare to guide students by working through these processes themselves.

One productive format for learning to "do" science is a study group in which teachers explore a topic together. In the third year of the Cheche Konnen project, the researchers worked with a group of eight Boston teachers in a series of biweekly meetings. Teachers began to study water, taking pH measures of several local water samples and discussing their results, observing the development and behavior of tadpoles and microscopic aquatic life. Their observations led to questions such as: How should I represent the pH of this water when different people get different measurements for it? Why did my tadpole die when I changed the water? Why does one water sample have so many of this organism while another one does not? Once a study group has done some

Margin Notes

The approach requires a commitment from bilingual teachers and other personnel. Additional meeting and planning time may be needed throughout the school year and in the summer. Districts should anticipate the need for stipends before undertaking the program. They should also anticipate the need to order science equipment and supplies.

observations, taken data, and developed some questions and hypotheses, they might invite a volunteer from the science community to join them, not necessarily to provide answers, but to suggest strategies for pursuing their questions,

Cheche Konnen requires a significant commitment of time and effort on the part of all concerned, but especially on the part of bilingual staff. Despite in-school preparatory hours, staff will devote many hours outside of school to develop a program of scientific inquiry for their students. While it is not possible to compensate teachers fully for the time they spend in this regard, their efforts should be recognized and rewarded with a stipend or honorarium. Teachers participating in the Cheche Konnen field test received a stipend for their involvement in both years of the project. However, it is interesting to note that although the project is over, these teachers are continuing to develop collaborative scientific inquiry—and new teachers are joining the effort—without the prospect of financial reward.

Teachers should be paid during the summer to record the investigations their classes develop during the year. These "investigation guides" can include, for example, student work, teacher materials, and important resources. The guides can be used by other teachers interested in doing collaborative scientific inquiry. Sample investigations conducted during the field test are reported in *Cheche Konnen Investigations, 1988–1989; 1989–1990* by Rosebery, Warren & Conant.

Finally, if possible, a small fund for science equipment and materials should be available to teachers throughout the year. In most systems, teachers must order their materials in June of the previous academic year. This process seriously limits the extent to which teachers can support student-generated investigations as they form in the classroom. In the water investigation, students used microscopes, Millipore Samplers for bacteria, silver nitrate for salinity tests, litmus paper, and several aquaria. Some of the equipment was available in the school; other materials had to be purchased. To conduct their weather study, the Kindergartens needed thermometers, a camera and film, an anemometer, paint to make a playground compass, and large posterboard for graphs. Again, the school was able to supply some of these materials but others had to be purchased, begged or borrowed. The Polaroid Company, for example, has a program in which they give a school or classroom a camera free of charge if $100 worth of film is purchased.

Barriers and Solutions

The biggest challenge in adopting Cheche Konnen is teacher training. Cheche Konnen places formidable demands on bilingual teachers. It asks them to tackle a discipline, science, that is new and, in many respects, intimidating. It asks them to change their teaching practices away from textbook and worksheet-based instruction toward inquiry-based, collaborative learning. It asks them to design scientific investigations. And it asks them to integrate disciplines—science, math and literacy—that are independent of one another in the conventional curriculum. Finally, it asks them to let students "control" the course of instruction, through the questions they ask and the investigations they design.

By far, the most difficult aspect of implementing Cheche Konnen is helping teachers understand (a) what inquiry science is and (b) how to promote it in the classroom. Significant time and effort must be devoted to teacher enhancement before and throughout the life of the innovation. This can best be accomplished through a series of intensive summer and after-school workshops. For example, in the field test, researchers held week-long summer workshops which were continued on a monthly basis during the school year. These workshops focused on four principal components: teachers doing science; teachers developing scientific investigations; teachers teaching science; and teachers evaluating classroom practice. We discuss each component briefly, with special focus on its purpose, rationale, and expected outcomes.

Margin Notes

Teachers Doing Science

Bilingual teachers are generally inexperienced in teaching science and, in some cases, even in learning science. We believe that for teachers to know what it means to *do* collaborative inquiry in science, they must first experience it themselves. To this end, an enhancement program must include a strand in which teachers formulate and carry out scientific investigations in which they explore their own ideas collaboratively with other teachers and, where possible, under the guiding eye of scientists from the local community.

As part of the inquiry process, teachers should begin to reflect on themselves as learners and as teachers. As learners, they need to reflect on how they are making sense of the phenomena they are confronting (e.g., what they think and why) and on how they and others involved in the process are "talking science." According to Duckworth (1987), learning takes place in the effort to explain to others and to understand others' explanations, and in the effort to produce knowledge collaboratively through active theorizing, experimentation, and the like. Videotapes of the teachers as they do and talk science are invaluable for this purpose. As teachers, they are asked to reflect on the collaborative inquiry process itself, on its structure and on its salient features (e.g., how theorizing is accomplished in the context of data, how questions are transformed into hypotheses that can be evaluated empirically, how teachers can help their students make sense of their scientific inquiries). Through this kind of reflection, the process of learning science and teaching science are explicitly linked. In effect, through their learning, the teachers experience and then analyze the very process they are expected to bring about in their classrooms.

To be able to teach collaborative inquiry, teachers should have direct experience in doing collaborative science. To understand what doing science entails, teachers should conduct their own investigations.

Teachers Developing Investigations

This component of the teacher enhancement process is a direct outgrowth of the first. Having developed an understanding of what it means to do collaborative inquiry in science, teachers begin to develop investigations for their own classrooms. In many cases this means adapting existing, high quality materials to a collaborative inquiry approach rather than creating materials from scratch (e.g., Elementary Science Study units available through ERIC).

The activity of developing investigations serves to continue and expand the first phase of enhancement, focusing on the constructive aspect of design as a complement of inquiry in the development of one's scientific knowledge. In effect, the idea is to challenge the trend in science education that has predominated during the past couple of decades. Rather than produce "teacher-proof" curricula, our aim is to produce "curriculum-proof" teachers, that is, teachers who have the knowledge, skill and independence of mind to adapt materials to their own purposes. Through this component, the teacher enhancement process promotes not only good teaching practices but also good curricula.

Teachers Teaching Science

In practice, collaborative inquiry poses many challenges to teachers who are on the one hand unaccustomed to teaching science and on the other accustomed to being the center of learning. For example, collaborative inquiry means that students by and large control, under the guidance of the teacher, the learning process through their own intellectual activity. Collaborative inquiry also

Margin Notes

"Not knowing" the answer to a problem should be considered a challenge rather than an obstacle to learning. In collaborative inquiry, teachers and students redefine their traditional roles and approach science as a joint venture.

This section discusses the ways teachers can evaluate their own progress as collaborators in inquiry teaching. The researchers suggest that teachers use techniques of ethnography to observe and analyze how their practice evolves.

means that teachers may find themselves in a state of "not knowing," either because the investigation is about a real question or because new, unanticipated questions arise as a consequence of the class' activity. The teacher's challenge in such cases is to transform the problem of "not knowing" into an opportunity for collaborative inquiry rather than treating it as a failure or an end point to inquiry.

To accomplish this, teachers need to initiate new patterns of teacher-student interaction that redefine the roles and responsibilities of both with respect to learning and knowing. There is no script for these kinds of interactions and discussions; skill in managing them comes about through experience and critical examination of the goals and assumptions that inform one's own classroom practices. Skill in managing them also crucially derives from a knowledge of the nature of scientific activity, and how it can be organized in the classroom. In this phase, then, teachers put into practice the models of scientific inquiry they have learned and the investigations they have developed in the previous phases. They have the opportunity to test and refine their ideas and their investigations in the classroom under the supportive eye of other teachers, administrators and, perhaps, scientists. This group functions as a resource to help teachers address both disciplinary (e.g., scientific, mathematical) and pedagogical problems that arise in the daily practice of teaching.

Teachers Evaluating Classroom Practices

For teachers to become fully independent in the practice of an innovation, it is essential that they have means for assessing in an ongoing fashion their own teaching and their students' learning. In this section, we address techniques that can help teachers observe and critique their classroom practices as they relate specifically to the development of students' scientific literacy. Student assessment is discussed in "What Do I Do?"

One powerful method of assessing classroom practice is to analyze classroom discourse, that is teachers' and students' ways of talking and doing science. Aspects of classroom discourse in science that are especially key to the collaborative inquiry process include: the kinds and purposes of questions; the elaboration, analysis and critiquing of theories; the interpretation of data; the forms of explanation and their use in understanding data, arguing a theory and building a model. In this phase, teachers can learn to use techniques of ethnographic observation to assess discourse practices in their classrooms. Among the techniques with which they can become familiar are audio- and videotaping classroom discussions; analyzing the tapes and related materials (such as texts the students read and write, texts the teachers prepare, students' work); and keeping a journal to record observations and reflections (akin to an anthropologist's field notes). The purpose of such analyses is to make explicit the assumptions, expectations, values and understandings that underlie teachers' and students' scientific talk. As these are understood, teachers can begin to create richer opportunities for developing students' scientific understandings (cf. Heath, 1983). This is particularly important in the education of language minority students whose home-based literacies (e.g., ways of talking and knowing) often do not fit, and at times may even conflict, with the school-based literacies they are expected to acquire (e.g., ways of talking, knowing, reading and writing in science, mathematics, etc.).

What Do I Do?

Margin Notes

What does collaborative scientific inquiry for language minority students look like in the classroom? What kinds of behaviors should be encouraged in students? In teachers? In this section, we address these questions, beginning with an example of an investigation conducted in the first year of the field test by 7–8 grade Haitian students.

Water Taste Test

For a month or two, the class had studied the chemical, biological and physical characteristics of water, learning about pH, bacteria, salinity, turbidity and the like. Prompted by their teacher, they used this new knowledge to investigate a common myth in the Junior High classes of the school: that the water from the fountain on the third floor (where the Junior High is located) was superior to the water from the other fountains in the school. As in authentic science, the students' investigation grew in ways that were not pre-determined but that evolved directly from the results of their scientific activity. Eventually, their investigation grew to include three stages: a class taste test, a junior high-wide taste test, and an analysis of the water in the school's fountains. We recount each stage briefly.

This section explains how the Cheche Konnen approach was used to set up collaborative inquiry in a class of 7–8 grade Haitian students. Briefly, their teacher had noticed that most of the students in the 7–8 grade drank only from the third floor fountain because they believed that the water was better than the water from other fountains.

The teacher challenged the students to test this idea. They then organized a water fountain taste test. The results didn't turn out the way they expected, so they suggested testing more students. Again, their results were surprising, so they decided to conduct experiments to explain their results.

Class Taste Test

The students' initial investigation grew directly out of their belief that the water from the third floor fountain was superior to that from the other fountains in the school. To determine whether they actually preferred the third floor or only thought they did, they conducted a 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 confirm or challenge the students' belief.

As part of the blind taste test, the students completed a questionnaire and tasted water samples, the identities of which were concealed. The questionnaire asked them to identify the water fountain they preferred to drink from, the fountain they drank from most often, and then, after tasting the samples, which water they liked best. The students expected that their pre-taste test preference, the third floor, would, in their words, "win." They also expected the first floor water to receive no votes because it was regarded as the worst water in the school since "all the little kids slobber in it."

When they analyzed their data, however, they found that while they all said they preferred drinking from the third floor fountain, in the blind tasting, two-thirds of them chose the water from the first floor. The data struck both the teacher and the students as odd. The students felt that "the thing didn't come out right" because it had not confirmed their belief; the teacher thought that the students had biased their results by speculating about the identities of the samples. Everyone, in short, was skeptical about the validity of the data. This led the class to conduct a second experiment with a larger sample.

Junior High Taste Test

In the next class, with minimal guidance from their teacher, the students planned a larger water taste test. They started by tackling logistical issues: where to do the taste test, when, and on whom. With some prodding from their teacher, they decided to limit the taste test to the mainstream 7–8 classes. 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

Margin Notes

the voting process: what if some students voted twice? As class came to a close, every student took responsibility for some part of the study.

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 mainstream students came up to the table, they were handed a questionnaire and three water samples. Approximately 40 students participated.

Once the taste test was completed, the students returned to class to tabulate and analyze their data. They were surprised to find that their earlier results had been confirmed: 88% of Junior High students thought they preferred the third floor water but 55% actually chose the first floor water! (If there were no differences in the water from the three fountains, one would expect each to receive 33% of the votes.) Students graphed their findings and hung them on a kiosk outside their classroom. They wrote reports of their findings and composed an announcement for the principal to read over the school's public address system.

Analysis of School Water

Now the class had a final problem: *Why* was the first floor water preferred? To determine the source of the preference, the class embarked on an analysis of the school's water fountains, investigating three variables: salinity, bacteria and temperature.

The results presented the students with an interesting problem. Their findings on salinity were inconclusive. In contrast, they found that all the fountains in the school had unacceptably high levels of bacteria, and that the first floor (the one most preferred) had the highest counts! The class reported their bacteria findings to a chemist at the local water authority who suggested that their samples had been contaminated. He agreed to retest the water on the condition that the students promise not to publish their results in the local newspaper! The students also found that the water from the first floor fountain was colder than the water from the other floors. To account for the observed temperature difference they developed a theory that the water was naturally cooled during the winter months (the study was conducted in February) as it sat underground in city pipes and warmed as it traveled from the basement to the third floor. In the end, they decided that temperature was probably an important factor in taste preference.

Here, the researchers describe the ways the students drew upon community resources in their research by sharing their bacteria results with a chemist at the Water Department. After recording temperature data, the students developed some hypotheses about why the water from one fountain was preferred over the others.

As a result of their research, the students participating in the project came to be seen as experts on water by the rest of the school. Their knowledge and hard work enhanced their social and intellectual position in the school.

The Water Taste Test, as we have come to call the entire investigation, was a valuable experience for these students for at least two reasons. First, they experienced science, mathematics, and literacy (talk, reading and writing) as useful and purposeful. Their knowledge of these disciplines expanded naturally as the investigation expanded. They learned to plan and carry out experiments. They learned how to collect, analyze, graph, and interpret data. They took the first steps in learning how to read and write scientific reports. They learned and used English as they interacted with the local school and city communities. In short, they experienced learning as integrated and meaningful.

Secondly, and equally as important, the investigation altered the students' intellectual and social position within the school. Prior to the Water Taste Test, they were separated from the mainstream of life in the school. Their investigation, however, put them in the spotlight. As it became public, the administration, faculty and their fellow students acknowledged them as experts on water. They were seen as special in the best sense of the word because they knew things that other students (and teachers) did not.

Conducting Investigations in the Classroom

Margin Notes

We now elaborate on the four most important features of the Cheche Konnen model with reference to examples from the Water Taste Test and other student investigations: collaborative scientific inquiry, mathematics (data exploration and analysis), literacy, and the role of the teacher.

Scientific Inquiry

■ **Students' questions**

As we have said elsewhere, Cheche Konnen investigations are developed from students' questions and beliefs. How does this happen? In the case of the Water Taste Test, the teacher capitalized on a belief her students held. This teacher had observed that her students avoided drinking from any fountain but the third floor and had heard them discuss its superiority. She confronted them with their belief and challenged them to find out if what they thought was "true." (Throughout the year, this teacher reinforced for her students that science is a process of distinguishing what one believes from what is "true.") When they were first challenged, the students fully expected that their belief would be confirmed: that the third floor water would "win." (They perceived the taste test not as a way of determining a group preference but as a test to see who could pick the "right" sample of water.) When the results did not come out as they expected, they were horrified and suspicious but, most importantly, perhaps they realized the power of the blind taste test design. This led them to re-evaluate both their beliefs and their experimental design, finally deciding to redo the experiment with a larger sample.

The role of the teacher in encouraging critical thinking should not be underestimated. The 7-8 grade teacher, for example, constantly challenged her students to distinguish between their beliefs and scientifically verifiable knowledge. She encouraged them to test their theory about the water even though neither she nor the class knew in advance how the experiment would turn out. This open-ended inquiry approach enabled the class to enlarge their investigation to one that would explain the differences in the perceived taste of the water.

The evolution of the Water Taste Test from students' beliefs demonstrates the role of questions in motivating and pushing forward an investigation. Each step in the investigation gave rise to new questions which in turn presented authentic scientific problems for the class to consider (e.g., bias, sample size, comparability of data, reasons for preference). When the teacher and students conducted the class taste test, neither knew whether the results would in fact confirm or challenge the class' belief. Yet the following weeks of the study depended on these results and their interpretation. When the students' beliefs were not confirmed by their initial experiment, new questions arose leading to the second taste test. These findings in turn motivated the question that drove the final stage of the investigation: *Why* did the students choose the first floor fountain over the other floors? Thus, although well-defined in terms of its objective (to determine which water was preferred and why), 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 it from one that sought to *demonstrate* differences to one that sought to *explain* those differences.

■ **Hypotheses**

The researchers explain the role of hypothesis formation in scientific inquiry.

Students' questions and beliefs mark the beginning of an investigation and, in later stages, may focus or broaden its scope. But for experimental purposes, questions must be transformed into *hypotheses*, specific statements that are testable and that suggest how something is expected to turn out.[2] Hypotheses help organize an investigation, focusing the students' inquiry on particular aspects of a problem. In the Water Taste Test, the students' hypothesis—that they would prefer the third floor water in a blind taste test—derived directly from their belief of the third floor fountain's superiority and, implicitly, from their belief that they could distinguish it from the others in a blind test. In short, their hypothesis assumed the truth of that belief and their investigation tested that hypothesis.

Margin Notes

Students begin to not only evaluate their beliefs but to create investigations to test actual hypotheses. The students in the 7-8 grade had a naïve belief about the water when they started; later they were able to use this belief and their subsequent experiments to develop a "theory."

In the Water Taste Test, the students' belief—that the third floor water was better because the little kids did not contaminate it—was implicit. Once armed with convincing evidence to the contrary, the students formulated a theory to explain their findings.

Professional scientists are concerned with the integrity of their research design. Here the researchers describe the steps the students took to ensure that their experiment would not be compromised.

The researchers note that involving the students in designing research gives them first-hand experience in making scientific decisions and critiquing their work.

Theories

As the Water Taste Test example shows, hypotheses are not mere guesses. They are informed conjectures: they are put forward in the context of some belief or theory about *why* things should turn out one way and not another. From a scientific perspective, students should generate and test hypotheses for the purpose of developing and evaluating *theories* about the phenomena they are studying.

Initially in the Water Taste Test, the students were simply evaluating their belief; they were not evaluating a particular, explicit theory about why they preferred the third floor fountain. If there was a theory underlying their belief, then it was an implicit one not expressed in testable terms: that the third floor was better because it was not contaminated by the little kids. As the investigation shows, it took two taste tests for the students to begin to let go of their belief and consider possible explanations for their results. The last stage of the investigation, in which they tested the water fountains for bacteria, temperature, and salinity, reflected this shift in focus, away from simply evaluating their belief to developing explanations for the experimental results. In this phase, hypotheses functioned as the building blocks for theories about the cause(s) of the differences among the water fountains.

Experimentation

Once formulated, hypotheses are evaluated through experimentation.[3] In the Water Taste Test, students made use of a blind taste test model to which they had been introduced at the beginning of the year (see "Pepsi Challenge" activity, described in Rosebery, Warren & Conant, 1990b). In order to use it for their own purposes, they reasoned through the design of the Pepsi Challenge and adapted it to accommodate their needs.

For example, in planning the Junior High Taste Test, some students in the class were concerned that the mainstream students would take the taste test more than once and contaminate their sample. To address this, one student suggested taking a photo of each student. The teacher countered that this might be difficult to implement and the class finally decided simply to have each student sign in before "tasting." They also debated how to guard the identity of the different fountains: Should they all know which was which or should only one student be in charge of "keeping the secret?" They decided on the latter for fear that security would be breached if the fountains' identities were known to everyone in the class.

Having students debate these kinds of issues and make decisions about exactly how to design and implement their study is crucial. It helps them develop the sense that their scientific activity is serious, purposeful work and that they are responsible for seeing that it gets done well. In effect, it puts them inside the scientific process; they do not merely execute someone else's design but define and shape one of their own. And because they own the design, they can more readily reflect on its strengths and weaknesses as the study unfolds. In most school activities, by contrast, students are told not just what to do but how to do it, limiting the number of opportunities they have to exercise intellectual initiative and creativity.

The Water Taste Test is only one example of collaborative scientific inquiry. Any topic that lends itself to students' questions and that presents the opportunity to collect data will work equally as well. Topics investigated by other Cheche Konnen classes are described in Overview of the Field Test. In each there was an emphasis on student hypotheses and experiments (or observation, description and field methods), data collection and analysis, mathematics and literacy. In one of the more observational studies, for example, two Kindergartens, one Haitian and one mainstream, collaborated on an investigation of their local weather. Twice a day they collected data on such variables as temperature, wind speed and direction, and clouds, using thermometers, anemometers, a compass painted on the playground and Polaroid cameras. They created a large data chart which included graphs of temperature, wind direction and precipitation, as well as reports the students made of their cloud observations. Later they used the chart to develop and investigate questions about weather such as: What kinds of clouds make rain? Why does the wind sock blow one way and the clouds go another? Why do clouds go from west to east sometimes and from north to south other times? Does it always get colder when it rains? Why do the clouds change so fast?

In the second year of the field test, a new group of Haitian 7th and 8th graders conducted an investigation in which they tested their hypotheses that people who eat a lot of salt are fat, have high blood pressure, and are out of shape. They determined the kinds of information they would need in order to answer their questions and they collaboratively devised ways to get that information. For example, they designed a salt consumption questionnaire to determine relative salt consumption (see Figure 3, page 34). They analyzed and translated their concepts of "fat" and "out of shape" into quantitative terms. In the first case, they measured the heights and weights of students in their class and then compared the results to national percentiles (see Figure 4, p. 35, for a student's data sheet). In the second case, they designed an experiment in which students' pulse and blood pressure were measured before and after running a flight of stairs.

Margin Notes

The researchers again point out that collaborative inquiry is an approach; the particular object of study can vary. Depending upon the grade level and other factors, a variety of phenomena can be studied using collaborative inquiry. For example, a kindergarten group studied weather while a second 7-8 grade class of Haitian students asked whether people who eat a lot of salt are out of shape.

Mathematics: Data Exploration and Analysis

In carrying out their investigations, students collect data principally through experimentation and observation. Like scientists, they then use statistics to make sense of their data. In the Water Taste Test, for example, students were introduced to basic techniques of data exploration and analysis, including graphical representations, descriptive data analysis (measures of center such as mean and median), and interpretation.

After holding the Junior High Water Taste Test, for example, the class was faced with the task of collating and tabulating the data from 40 questionnaires. Three students were put in charge of the job: two read the raw data from the questionnaires and a third student recorded it on a large table he made on the blackboard. After recording the data, they tabulated their results. Each student in the class then graphed the results in his or her science notebook. Because different students had represented the data in a variety of ways (some made horizontal bar graphs, some made vertical bar graphs, some created unique representations), they discussed which of the graphs best depicted the data. In this discussion the students thought deeply and analytically about the connection between data and graphs, on the one hand, and between the meaning of their data and how to express that meaning to others, on the other. In these ways, in contrast to most mathematics classes, students experience mathematics as a meaningful mode of scientific expression precisely because they use it to answer questions they themselves pose. Mathematics becomes an integral tool in students' own knowledge-producing activities.

Another example of Cheche Konnen's potential for promoting genuine mathematics use was demonstrated in the Kindergarten weather study. During their year of collecting, recording and analyzing data, these students began to acquire basic numeracy. As one of the Kindergarten teachers reported in an end of the year interview:

> This is the first year that our students have ever learned numbers [so] high...they know how to count from one to a hundred...We also used the weather calendar [to teach] subtraction and addition. Each bar had 9 squares on it; the kids would look at that bar and they'd find out that

Once data was collected, the students began to analyze it. They used statistical procedures (both mathematical and graphical) to describe and interpret their data.

They developed graphic representations of the data—bar graphs, for example—and discussed the best ways to present their results.

Margin Notes

there were five days colored in, how many squares not colored in: four; five plus four is nine. From there we went to using a large bar graph; they'd read the thermometer and record [the temperature] on it.

A second benefit of Cheche Konnen's collaborative inquiry approach was introducing Kindergartners to sophisticated mathematical reasoning. These young students learned that mathematics is a tool for acquiring knowledge.

In addition to basic numeracy, the Kindergartners used their data to begin reasoning quantitatively. For example, they used the bar graph of daily temperatures mentioned by the teacher to look for patterns and trends across time; they examined wind speed to see if changes in it accompanied changes in weather; they speculated on the relationship between number of anemometer revolutions and miles per hour in wind speed. Traditional Kindergarten mathematics activities do not motivate this kind of mathematical reasoning. By using mathematics to answer meaningful questions, these students were able to learn more mathematics than is standard in Kindergarten, but more importantly, they began to appreciate the potential of mathematics as a tool in the pursuit of knowledge.

Literacy: Talking and Writing Science

In Cheche Konnen, literacy activity grows directly out of the students' scientific ventures. Students begin to think, talk, and write scientifically by doing science.

■ Scientific talk

Talk is essential to the development of scientific understanding. Without it, students' meanings remain implicit and conflicts in belief or evidence cannot be negotiated. In Cheche Konnen, students do a lot of talking; it is an integral part of their scientific activity. They plan investigations together, they report observations to one another, they pose questions to one another, they debate how to classify or describe specimens uncovered in the field, they try to build theories to explain data they have collected, they interact with the English-speaking community both within the school and beyond.

Talk is critical to the Cheche Konnen approach. Through talk, students develop scientific understanding. For example, students talked about their experimental design, the implications of their data, and the best ways to represent it.

In the Water Taste Test, for example, students learned to talk about data (using terms such as mean, median, and graph), and experimental design (using terms such as experiment, test, and sample). They also learned to talk about ways of representing data. In class, the 7–8 graders graphed their class taste test data. One student, Carlyne, produced a bar graph for the preference data. Another student, Alan, questioned whether it was "right." As he articulated his criticism of Carlyne's graph to the class ("Here's what I don't understand about hers. It's the second floor that...they like best, but she marked the first floor..."), it became clear that he thought the graph represented the blind taste results, not the preference results. His reasoning so impressed the other students (even though he'd been mistaken) that when it came time for each student to graph the data in their notebooks, several approached Alan for help. Through talk, by questioning Carlyne's representation and articulating his criticism, Alan established himself in the eyes of his peers as an expert in graphical representation and also worked through his own misunderstanding of Carlyne's graph.

■ Scientific writing

In addition to talking science, students compose texts, scientific and otherwise, as they conduct their investigations. For example, each student in the Water Taste Test class kept a science notebook in which he or she recorded daily scientific activity. Some days this meant recording data or creating a graph; other days it meant describing observations of an experiment; still other days it meant writing a summary of one's findings. Students' entries varied in length according to their writing proficiency, but all students were motivated to articulate the sense they had made of their scientific activity that day.

One student composed the following summary of the Water Taste Test. Her summary reflects her struggle to create a scientific text, that is, one that both describes the class' activity and also presents their scientific thinking and findings.

> 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.

Although her summary lacks many of the explanatory, theoretical and evidential conventions of scientific writing, it begins to tell a story about students doing science.

As well as introducing students to the writing of scientific texts, the Water Taste Test provided a powerful context for English language development. As the students moved out of their classroom to communicate with the larger school and city communities, they used both spoken and written English. For example, they wrote letters to water quality experts in the community to obtain technical information and to arrange field trips. For the Junior High Taste Test, they composed a questionnaire on water preference in English in order to collect data from their monolingual peers. And later, at the principal's request, they submitted a report of their results to be read over the school's PA system.

Recording observations, collecting data, and writing up experiments are only a few examples of the opportunities science provides for literacy development. In the high school pond study, for example, students composed plant and animal data questionnaires. Back in the classroom, they used microscopes to observe the microscopic life they collected and recorded observations of their forms and behaviors. They wrote questions with which to interview a local water chemist. And they compiled their observation notes, plant and animal data, and measurement reports into an illustrated field guide (see Figure 1, p. 32). For her Field Guide report, one student struggled productively with various discourse forms as she tried to make sense of temperature data she and others had collected at the pond (see Figure 2, p. 33). The writing that resulted surpassed anything she had been required to do in class prior to the pond investigation.

In the Kindergarten weather study, opportunities for literacy development arose on a daily basis. For example, each day, a group of children would report the weather to the rest of the class based on their outdoor observations, including their description of clouds. In these cloud descriptions, students developed language to differentiate, categorize and compare cloud formations (cover, form, color, movement, and height). For example, they developed contrasts between clear skies (the clouds are open) and overcast skies (the clouds fill the sky; the clouds can't be counted). They also distinguished color, form, and height, and used the compass directions to characterize the direction of cloud movement. This latter dimension emerged as important when the students began to monitor wind speed and noticed that the clouds didn't necessarily move in the same direction as surface winds. As their reporting progressed, the Kindergartners were prompted to articulate questions such as "What makes the clouds change so fast?" and then to posit explanations. In addition to reporting to the class, the "weatherpersons" would record on their large weather chart data such as wind speed and time of observation and would dictate their cloud observations to the teacher. In this way, they were able to compare clouds and other weather phenomena across time and conditions.

Margin Notes

Professional scientists write for many purposes. In Cheche Konnen, students also wrote throughout their investigations. They kept "lab notebooks" to record their scientific activity, including field observations, data, and comments on experimental design.

They also used writing to understand their results and communicate them to the school community.

In the Kindergarten classes, the students' observations about clouds led to descriptive writings.

Although students were taught bilingually, they learned more and richer English than they typically would have in a standard ESL class.

Margin Notes

Each of the activities discussed above provided students with diverse opportunities to develop English. Moreover, through authentic engagements with the language, students learned more and richer English than they typically do from standard ESL. It is opportunities like these that make collaborative scientific inquiry especially valuable for language minority students: Any investigation which involves data collection outside of the bilingual classroom becomes a lesson in English and one in which students readily engage.

Role of Teacher

In Cheche Konnen, the emphasis on active inquiry, data collection and analysis, theory building and the like is intended to highlight new roles for students and teachers in the educational process. We imagine both as active investigators. We have already talked at some length about students' roles. Our purpose in this section is to reflect on the teachers' role in this new community of practice.

Ideally, teachers are active investigators on several fronts: as co-investigators with their students of specific questions; as teachers who help their students make sense of their activity and their understanding; and, as innovators, who continually build and refine a culture of authentic scientific practice in their classrooms. In Cheche Konnen, the traditional role of the teacher as one who dispenses knowledge and assesses whether students have learned it is displaced by a new role. It is one in which the teacher assists the students in building understandings of phenomena in the natural world or, as Duckworth (1987) puts it, one in which the teacher engages learners to make sense of the world, to communicate their understanding to others, and to test their understanding against what others think. In this new role, the teacher steps back from posing all the questions, doing all the explaining and evaluating all the answers, letting these become, for the most part, the recognized and valued responsibility of students. Duckworth (1987) observes:

> The essential element 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 or 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.

In the Cheche Konnen model, the teacher's role changes dramatically from regular classroom instruction. Teachers are active investigators on several fronts: as co-investigators with students; as teachers who help their students make sense of their activity and communicate their understanding to others; and as innovators who are building a culture of authentic scientific practice.

In the classroom, the teacher steps back and does not attempt to provide all the answers and explanations; instead, she lets students construct their own understandings through collaborative inquiry.

This does not mean that in a sense-making community, the teacher is silenced. To the contrary, teachers are essential players in sense-making. Rather than reinforcing correct answers, for example, teachers now have the responsibility to challenge a student's explanation to make sure he or she understands it and that others in the class also understand it. Similarly, teachers have the responsibility to make sure that they, too, understand what sense the student is making and why. The whole point is that, starting from students' questions or beliefs, teachers and students work together to build understanding.

Of course, there will be times when the teacher will need to model new activities or provide students with resource materials. In these cases, it is important that these activities be introduced in the context of students' inquiry and that they serve some useful function inside the students' activity. For example, to develop the pond Field Guide, teachers helped students learn to use litmus paper, interpret the pH scale, and gave them materials on the effects of acidity on water and aquatic life. In the salt-study, students used charts from the nurse's office in order to determine percentiles of heights and weights for their subjects. In order to use these charts, students had to learn about percentiles. In both of these studies, teachers provided the students with new tools that enabled them to go forward with their research.

During an investigation, a teacher needs to become comfortable with students as they work independently in small groups. In collaborative inquiry, students are encouraged to work together and to share expertise and ideas in order to answer large questions or to conduct complex investigations. Giving different groups responsibility for different parts of a project not only makes it possible for an investigation to have an increased scope, but it gives groups of students the opportunity to develop expertise in the area of a project which interests them and which they then become uniquely qualified to share with the classroom or community. In the high school study of the water quality of Black's Nook Pond, different groups recorded pH, temperature, bacteria counts, length of the pond, and so forth. Although it may be initially intimidating for a teacher to relinquish her place at the front of the classroom and to have several different activities going on simultaneously in the classroom, the students' combined contributions result in more dynamic and comprehensive investigations.

In addition, teachers new to scientific inquiry may be uncomfortable dealing with questions to which they do not know the answers. Moreover, in situations in which they feel they do know the answers, students may design experiments and investigations which are flawed. Although it may be tempting to correct a student's idea and supplant it with one's own, this is actually counterproductive to the development of students' reasoning. Students need to have first-hand experiences in designing and revising their own ideas. Rather than thinking that students will learn something that is "wrong," teachers must help students reason through inconsistencies or problems that may exist in their theories or experimental designs by asking them to articulate and explain the basis of their thinking. In this way, students can argue and solve the problems together and construct knowledge for themselves that will ultimately be deeper than that which is provided by a teacher.

There will also be times when an experiment does not produce the expected results, or "fails" altogether. This is not an experience unique to classrooms; scientific experiments in the real world fail as well. It is imperative, however, for the teacher to know that a failed experiment does not represent a failure in learning or teaching. On the contrary, it is a tremendous opportunity for learning. Like practicing scientists, students can learn as much, and arguably more, in understanding why an experiment has failed than in pulling off a "perfect" one. Understanding why an experiment has failed involves the kinds of critical analysis and higher level thinking which lie at the heart of real science. For example, in one field test classroom, groups of students tried to grow bacteria cultures, only one of which succeeded. The teachers in the room responded to the situation differently. Two abandoned the bacteria study because of their discomfort with the culture's failure. A third worked with students to hypothesize explanations for the failure with the goal of redoing the experiment successfully. In this way, students had the opportunity to review and analyze their experiment and to think critically about their methodology.

Collaborative inquiry of the kind outlined changes the conventional teacher-student relationship in which the teacher knows the entire sequence of things to be learned and how they are to be learned. In Cheche Konnen, in contrast, both the teacher and the students are co-investigators; neither knows beforehand the answers to their questions or even the direction(s) in which their studies will evolve. Together and through direct contact with the phenomena they are investigating, students and teachers produce and evaluate the knowledge they need to answer their questions. In the process, they began to build a common ground of scientific experience and discourse.

Margin Notes

The researchers offer some advice about coping with flawed experiments. It is important to let students learn from their own activity even when it is poorly conceived. Ultimately, they will build a more robust understanding of scientific phenomena if they have to revise their experiments or modify their theories.

The researchers also suggest that the failure of an experiment should not be viewed as a failure of teaching. Many scientific experiments fail, but scientists learn from these failures. The teacher should work to keep the group from becoming disheartened: a failed experiment is an opportunity to develop new hypotheses and rethink the design.

Margin Notes

In this section, the researchers discuss the issue of assessment. This matter demands a thoughtful approach, since conventional testing procedures are ill-suited to collaborative inquiry teaching. Because students are engaged in the process of building scientific knowledge, it is more appropriate to assess their work toward that goal and the understandings they are constructing.

To assess students, the Cheche Konnen researchers recommend focusing on the students' performance as scientists—e.g., the students' actual work, their thinking, their products. The students' notebooks can be used as the basis for discussion between teacher and student, similar to writing conferences. By focusing on students' scientific activity, the teacher can better evaluate how well the students are progressing towards thinking, acting, and talking scientifically.

Assessment

Not surprisingly, collaborative scientific inquiry requires new ways of assessing student learning. In this regard, our focus has been on helping teachers learn to assess, in an ongoing fashion, the scientific work and activity their students produce during an investigation. In collaborative inquiry, it is often the case that students do not all learn the same things at the same time. Conventional testing procedures are therefore ill-suited to evaluating learning. What is needed instead is an approach to assessment that is project- or process-based (Gardner. 1988; Frederiksen and Collins, 1989), that is, one that represents a record of a student's actual scientific work.

This is the approach we recommend for Cheche Konnen. A typical project portfolio might include a student's initial questions, research designs, collected data, data representations, analyses, and interpretations, field or experimental observations, draft reports, final reports and comments and evaluations from peers and teachers. Non-written products might include classroom discussions, oral presentations, instrumentation, and the like. Teachers may find it useful to discuss students' portfolios with them on a regular basis so as to help them reflect on their own inquiry processes. Project portfolios fulfill at least two purposes. First, they serve as a repository for a range of information which the teacher can use to assess a student's intellectual development over time. Second, they are useful to the student, too, as a basis for self-monitoring.

Science notebooks can serve as a portfolio in the sense described above. In several of our field test classrooms, science notebooks were one of the main tools used to monitor student progress. In these classes, students wrote notes regularly (on a daily basis) during science class. Teachers used their students' entries to evaluate both task performance and comprehension. For example, some entries contained data from an experiment which were judged for the appropriateness of their representation or their relevance to the question of study. Other entries summarized the goal of the lesson or experiment. These were judged with regard to the extent that students understood and integrated the day's activity with the on-going investigation. Entries were also evaluated according to their number and the clarity with which they were expressed. One teacher used notebooks daily the first year and only sporadically the next. At the end of the second year she regretted not having made use of the notebooks as she had done previously. Notebooks gave her students a sense of continuity and focus and gave her a way to see how an individual student's thinking had developed over the term. Students also regarded their science notebooks as important. One of our teachers reported that several of her students from the previous year appeared in September requesting their science notebooks.

Class participation can also be an important assessment context. Throughout the course of the year, teachers can observe progress in classroom discussion, and small and large group science activity. For example, one of our collaborating teachers wanted her students to learn to keep their comments and questions on target during science discussions; this was not an art they had mastered prior to 7th grade. Thus, she was interested in evaluating her students' progress with respect to their ability to "stay on topic" during discussions. One way of doing this is to periodically record a class session and listen to it for the features of interest. From a conversational perspective, these can include turn taking, appropriateness of comments, paying attention to and respecting peers, and feeling confident about one's own ideas. From a scientific perspective, these can include question posing, theory articulation and building, use of data as evidence, ability to critique one's own thoughts, and the like.

Students can also be evaluated for the extent to which they participate in hands-on activities. The teacher's goal, of course, is for all students to be engaged in the scientific activity at hand, whether it be designing an experiment, collecting data, or learning how to use a microscope. It is also important for the teacher to note whether students are taking on different roles in their small group work. For example, the teacher might want to monitor whether certain students always take the "lead" role while others are passive.

Finally, the teacher can learn a lot about her students' progress by listening to and watching how they interact with one another. For example, in group projects, where a range of tasks must be matched to a range of abilities and interests, the students themselves are often adept at deciding which task best suits which student. In these situations, however, it is important to let the individual members know that they are responsible for the entire group's work and will be evaluated accordingly.

In summary, we recommend that assessment focus on students' activity, their thinking, and the products thereof. In this way, teachers can truly evaluate the extent to which students are learning how to talk, think, and act scientifically.

Results to Be Expected

Cheche Konnen effects broadscale change at many levels. Students develop academically, teachers develop professionally, and the school community evolves new forms of collaboration. In this section, we summarize the kinds of changes that can be expected in students, teachers and the larger school community as a result of Cheche Konnen.

Students

The major goal of the Cheche Konnen approach is for students to develop ways of scientific thinking, talking and acting. Not surprisingly, to evaluate the effect of Cheche Konnen on the development of scientific literacy, we examined changes in students' ways of thinking and talking. To assess change, sixteen 7–8 grade and high school students who had participated in the first year's field test were interviewed individually in Haitian Creole in the fall and late spring of the school year. For the better part of the year, they had conducted investigations into local water problems, The Water Taste Test and the Pond study. In the interview, the students were asked to "think aloud" about how they would investigate and try to solve two ill-defined but realistic scientific problems. One problem focused on pollution in the Boston Harbor and the other on a sudden illness that strikes several children in a school. For both, the students were asked to think aloud (report to the interviewer what they were thinking as they reasoned through the problem) about what they thought was causing the problem and how they would go about finding out if they were right. In our analyses, we were concerned with seeing if students' understanding of and use of hypotheses and experiments changed from the beginning of the year to the end. In the following, we summarize our findings (for full details and analyses see Rosebery, Warren & Conant, 1990c).

In the beginning of the year, the students showed no evidence that they understood what it means to reason scientifically and, specifically, to put forward hypotheses that can be evaluated through experimentation. Instead, it is as if they determined that the discourse context in which they found themselves was no different from that of most school tasks, in which literal comprehension is valued over inferential reasoning and in which questions are asked by a knowing teacher to ascertain whether the student has got the right answer. They did not adopt the perspective suggested to them by the interviewer in her introduction to the problem: "You are a famous scientist....What is the first thing you would do to find out what was wrong with the water?" Nor did they show any tendency to analyze the information given in the problem, to go beyond it, unless it was to use personal experience as evidence for a

Margin Notes

Two problems are presented to the students—the first dealing with water pollution and the second with illness. The students are asked to provide scientific explanations. The research collaborators note how much more scientific the students' responses have become.

Boston Harbor Problem

I'm going to tell you a true story; it's sort of a mystery. It's about the Boston Harbor. In the last few years, people have noticed that there is something wrong with the water in the Harbor but no one knows exactly what is wrong.

Fishermen have noticed that there are fewer fish in the Harbor. And they have seen a lot more algae. People who spend time near the Harbor have noticed that the water looks dirty; it is brown and foamy. It also has garbage in it. Tin cans, paper, and old food float in the water. Sometimes you can even see dead fish floating on the waves.

You are a famous scientist. The Mayor of Boston asks you to find out what is wrong with the water.

What is the first thing you do?
What do you do?

Margin Notes

In the problem below, the students are asked to explain an illness that runs through the school. Before being exposed to the Cheche Konnen approach, the student Elinor responds based on personal experience; later she formulated her response in the discourse of science.

Sick Kids Problem

I'm going to tell you another true story; it's a mystery, too. It's about some children in a school who get sick and, when it happened, no one knew what was making them sick.

It happened in a town around here, just outside Boston. All the children in an elementary school were watching a play put on by the sixth graders. Suddenly, a boy in the play fell off the stage and cut his chin. He said he felt sick and some teachers carried him to the nurse. Then a student watching the play got dizzy and fainted. Then some other students felt sick to their stomachs. Suddenly, lots of students were sick.

You are a famous scientist and you live next door to the school. When the children get sick, the principal runs over to your house and asks you to come and find out what is making the children sick. You agree and go to the school.

What is the first thing you do?
What do you think might be wrong with the water?
How will you find out if you are right?

At the end of the year, Elinor approaches the problem in a scientific manner. She puts forward two testable hypotheses, food poisoning or contagious illness, and suggests ways to test them.

particular belief. Rather, they limited the range of their thinking to what was contained in the problem statement itself, restating facts from the problem as if they were the "answers" to the interviewer's questions.

The reliance on personal experience as evidence for a belief is perhaps best exemplified in the protocol of one student, Elinor, who gave the following answer in response to the Sick Kids problem (see Margin Notes at left). The interviewer has related the problem to the student and asked, "What's the first thing you'd do?" Elinor gives the following response:

> Boko? [A spiritual healer] Like when you have an illness of Satan...you take them to a Boko. The reason I say it is a [Satanic illness] is because they all got sick at the same time. If it weren't Satan, they wouldn't all get sick at the same stroke. But why I'm not finished answering this more clearly for you, is because my grandmother was sick with a Satanic illness, we went to the doctor, and he didn't see that she had anything, ...and then she die....My grandmother wasn't into Satan and wasn't poor. She wasn't really rich, but she made a living. The place where I lived there were no cement houses...when my grandmother decided to build her house and my father's in cement, they gave her an illness...It's someone we knew, who sometimes came to my grandmother's house, who hated her.

In her response, Elinor takes a fact asserted in the problem story—that the children all got sick at the same time—and identifies it as a defining condition of Satanic illness. Her reasoning is largely based in personal experience but it's an experience very much at odds with what counts as scientific knowledge. In our analyses, we found that many students at the beginning of the year used personal experience—stories about grandparents, friends, self—as evidence that the phenomena described in the problem had happened rather than as evidence to explain those phenomena.

At the end of the year, there was a distinct change in the students' scientific knowledge, reasoning and discourse. They showed that they had acquired a great deal of knowledge about water pollution and, more generally, aquatic ecosystems. But more than that, they showed that they could use that knowledge productively in reasoning scientifically. They no longer limited the range of their thinking to the problem as given. They reasoned in terms of a larger system where that system was part of their knowledge base, as in the Harbor problem. Furthermore, they used hypotheses to organize and give direction to their reasoning. And they took the first steps toward developing a sense of the function and form of experimentation in producing evidence to evaluate hypotheses.

Elinor's end-of-the-year interview exemplifies these changes. In it, she responded to the Sick Kids problem in the following way:

> Elinor: I'd think it would be an illness someone had and he "contagioused" the ones sitting next to him, like one sat next to the other and got it and the next got it until everybody got it...If it's not that, it could be something they ate. They all might have eaten the same thing and it didn't agree with them...
>
> Interviewer: And if they had eaten, how would you know that what they'd eaten had done that?
>
> E: You could check all the foods...the meat could be spoiled or the milk. I'd check by giving it to another person [to eat].
>
> I: Excuse me?
>
> E: You take chicken and give it to a person to see what happens to the person. If nothing happens to the person, you take the milk and give it to the person, to see if the milk makes him sick.

Margin Notes

I: And if it were a contagious illness, as you said before, how would you know if it were?

E: You can take a sick person and put him next to one who weren't sick to see if the person gets it.

In contrast to her earlier interview, at the end of the year Elinor puts forward two testable hypotheses (contagious illness and food). The conditional "if not this, then this..." language she uses to organize her response also suggests that she is developing an awareness of the tentative nature of hypotheses as a methodological tool in scientific inquiry. It contrasts with the narrative "This is what happened..." style of the earlier interview. In addition, in the later interview, Elinor proposes procedures for testing her hypotheses. And, while her methods are ethically dubious, they are experimentally sound. For example, she understands the need to systematically isolate each variable for evaluation. Like other students in their end-of-the-year interviews, Elinor demonstrates an awareness that hypotheses drive scientific inquiry and that experimentation is a means for developing evidence with which to evaluate hypotheses. One of the Cheche Konnen teachers described the changes she observed in her students' thinking in the following way:

> I think that the kids' way of seeing the world, the way they think in general, has changed because they feel more comfortable learning on their own, investigating questions, thinking about questions and making them clearer, and finding out the answers whether from books or from experimentation. And most of all, I feel that they have made a step toward being critical about what people say to them...They're learning to find out for themselves and not listen to everything that they hear.

Teachers

During our two year collaboration with teachers, we observed many changes. Before summarizing them, it is important to put them in perspective by addressing the question: What were the challenges Cheche Konnen presented to teachers?

This section describes the impact of Cheche Konnen on teachers. The research team concludes that the teachers were the key to the success of Cheche Konnen. The teachers modified their instructional practices to become facilitators of scientific inquiry. Increasingly, students took the lead in initiating questions and directing discussions. These changes had a dramatic effect on the teachers; they felt empowered to teach collaborative inquiry as a result of their participation in the project.

Cheche Konnen challenged teachers on several fronts. First, it asked teachers who have little or no background in science to teach science, perhaps the most intimidating school subject. This meant that they had to develop new skills and knowledge. Second, it asked them to teach science in a new way, as inquiry. For all of the teachers, this approach was new and represented a departure from their usual classroom practice. As a result, the teachers found themselves in the position of having to rethink their goals as well as their own roles and their students' roles in the teaching and learning process. Third, Cheche Konnen did not provide a curriculum. Instead, it asked teachers to design, with support, investigations and become curriculum builders. Finally, it challenged teachers to integrate subject areas—science, mathematics and literacy—that are independent of one another in the conventional curriculum.

In planning this project, we hoped that through Cheche Konnen, teachers would feel empowered to experiment with new ways of teaching and learning. We also hoped that they would feel empowered to take control of their curriculum and help shape educational policies in their schools. In addition, we hoped that they would come to see science as a powerful vehicle for learning and for literacy development. And, finally, we hoped that they would come to see themselves not just as teachers but as learners, in two senses: as co-investigators with their students and as professionals who continually expand their expertise. We believe that each of these goals was reached to some degree.

Margin Notes

During the two-year field test, we observed dramatic changes in teachers' classroom practice. Whereas at the beginning of the project, the teachers tended to organize instruction around texts and worksheets, later in the project they organized teaching and learning around investigations grounded in students' questions. This was revealed in dramatic ways in an analysis we did of changes in teachers' questioning strategies from the beginning of the school year to the end. Early on, the teachers asked questions to which they already knew the answers ("Let's see if you can fill in the blanks in these two sentences." "Can you give me another name for soft drink?"). The students' answers were then evaluated on the basis of whether they were "correct" or not. As the year progressed, this questioning strategy virtually disappeared. Many of the questions started to come from the students. And, the questions teachers asked were intended to facilitate communication and inquiry rather than to define it ("How do you think you could find out whether salt affects fitness?" "How do you know that?" "What does this result mean?"). At the same time, we observed that the ratio of teacher to student talk changed over the course of a year. Teachers tended to talk less as the year went along while students talked more (from a high, in one classroom, of 13 teacher words for every one student word at the beginning of the year to two teacher words for every one student word at the end of the year). We also saw changes in literacy practices, away from worksheets to authentic communication. In the Basic Skills class at the high school, for example, rather than fill in sentence completion exercises, students worked on composing and producing their Field Guide. In the process, they actively negotiated in English word meanings and spellings, the narrative structure, details of their findings, and aspects of style. As difficult as the process of change was, the teachers felt energized by it. They could see the results daily in their classrooms. The 7–8 grade teacher, for example, saw her students' assume a new stance toward their learning:

> I felt there were some moments in the class when kids were taking control...for their own knowledge. For example, one time they asked to retest something because they felt there was a problem with the results. At other times, they would ask to do a different graph...But I think throughout the year...they were children who were making choices for their own learning.

The teachers enjoyed science, too, both as teachers and learners. They commented that they, like their students, learned science as a result of doing inquiry and designing investigations. Through Cheche Konnen, the teachers also assumed a new stance towards curriculum. They came to see it as something they control rather than as something controlling them. At first, the idea of developing investigations as part of the teaching and learning process frightened them. But as the year progressed, the power of the approach to build on students' insights and interests became clear and the teachers became forceful advocates of it.

We commented earlier in this Handbook that the teacher is key to the process of educational reform. This project has demonstrated the truth of that proposition. It was the teachers' willingness to challenge long-held assumptions about how to teach language minority children and how to think about learning in general that has helped produce the kinds of results reported here.

The School Community

Margin Notes

One effect of collaborative inquiry in science is that students move out of the classroom and into the school community where their scientific activity can be observed and appreciated. This recognition has positive consequences for the students' intellectual and social position within the school. It also creates new kinds of educational opportunities within the larger school community. Changes of this kind took place during both years of the field test.

Here the researchers summarize the effects of Cheche Konnen on the school community. Essentially, it led to improved relations between the mainstream and bilingual programs. This was an unexpected benefit. Too often, as the school principal notes, bilingual students are seen as the "them" in a "them and us dichotomy." But the Cheche Konnen students' research on a school-wide problem, water quality, challenged those perceptions. Increasingly, the Haitian students were viewed as individuals with valuable contributions to make to the school.

For example, the Water Taste Test elevated the social and intellectual status of the 7–8 grade Haitian students. Prior to that investigation, the students moved on the fringes of the school's community, rarely interacting with their English-speaking peers. As a result of the water investigation, the class was viewed with new respect. They knew things that other students (and teachers) did not. During the Junior High Water Taste Test, for example, a mainstream student said to them, "You know, what you are doing for us is very important." On another occasion, their teacher reported that several mainstream teachers had independently approached her and asked what was going on in her classroom—her students kept talking about "this thing called fecal coli—what is it?" The following year, the 7–8 grade class entered the school's science fair to collect additional data for their salt-study. This was the first time a bilingual class had entered the science fair. Students and teachers going through the fair were intrigued and impressed by the class' exhibit. In these ways, science helped to break down barriers between the bilingual and mainstream programs.

In an interview that took place at the end of the field test, the principal of the K–8 school characterized the changes that took place in the school community in the following way:

> In this school, there has been a tendency that the monolingual and the bilingual classrooms and students do not connect with each other because the bilingual program, in some ways, is a separate program. This has led to many negative consequences within the school. Students, both monolingual and bilingual, seeing each other as "them over there," kids not relating very well either in a social kind of way or within the classroom...The project has helped kids break down this barrier of the "them and us" and to see themselves as "us-es," just plain students. Kids have begun to see that no one group is either better or smarter than another group and that they are individuals and that they come with various kinds of information and possibilities. And so kids have been able to share with each other and, therefore, learn from each other.

This coming together of the bilingual and mainstream programs was most evident in the Kindergarten collaboration. This collaboration—between a bilingual and a mainstream Kindergarten class—proved an unqualified success. It strengthened the teachers' collegiality as they worked together both teaching and planning. It offered the students new opportunities to share ideas and experiences for meaningful purposes. They shared languages, teaching one another words in Creole and English; they shared ideas, asking and answering one another's questions; and they shared socially, working and playing together. Prior to this collaboration, the students came together only for so-called enrichment classes (music, art and gym). For the larger school community, the Kindergarten experience taught an important lesson in equality, demonstrating that language minority and language majority children can all learn the same things in the same ways. This belief was articulated by the bilingual Kindergarten teacher in an interview at the end of the school year:

An important outcome of the project was the collaboration among mainstream and bilingual kindergarten teachers. Both students and teachers benefited from the exchange.

> Even if people don't say it, it's in everyone's mind that bilingual children don't learn as fast as monolingual children. ...But we saw it

Margin Notes

> happen; we saw that the kids are equal. There might be a language problem but there is no learning problem. Maybe in September they couldn't do what [the mainstream] kids were doing, but we still have the same results.

The Kindergarten collaboration is now being viewed by the principal and teaching staff as a model for the entire school (see next section, "Concluding Vision").

In sum, our field test results show that students, teachers, and the larger school community have much to gain from the Cheche Konnen approach to science. When implemented effectively, the innovation has the potential to transform schools as well as classrooms into contexts for meaningful learning: students become active and independent thinkers; teachers learn to create environments for engendering student reasoning; and learning is shared throughout the school.

Concluding Vision

Students in the Cheche Konnen project not only met the challenges posed by complex scientific inquiry, but also improved their English language skills. The researchers point out that the use of a collaborative inquiry approach, in fact, helps resolve some of the tension between teaching specific subjects and teaching English.

Generally in bilingual education, there is a strong impulse towards oversimplification of the curriculum, owing in large measure to the need to develop language minority students' English skills. But such a strategy usually underestimates students' communicative and reasoning abilities. One result, however unintended, is that artificial limits are set on what language minority students can achieve and how they should learn.

Cheche Konnen, in contrast, has demonstrated that robust learning grows out of students' purposeful engagement with *complex*, ill-defined problems rather than mastery of oversimplified facts and procedures. Our research shows that language minority students are capable of meeting the intellectual challenges posed by authentic scientific activity. It also shows that this activity itself is capable of resolving the tension that exists between learning in a discipline such as science on the one hand and literacy development on the other, a tension that has troubled bilingual education since its inception.

Perhaps the most forceful testimony in support of our claims is the plan on the part of the K–8 school to expand the bilingual-mainstream Kindergarten collaboration throughout the school. According to their plan, English-speaking and language minority students will collaborate in science from Kindergarten through the eighth grade. But their plan goes beyond science. They are also considering extending the approach to other disciplines such as social studies, mathematics and literature. Their vision, therefore, includes cross-program as well as cross-discipline integration. The idea is not to dissolve the bilingual component into an immersion program in which the Haitian students only hear and talk English. Rather, the idea is to develop fully the concept of multicultural education in a multicultural community.

The school is motivated to undertake this experiment in order to equalize the educational opportunities offered to English-speaking and language minority students. Clearly, many difficult questions will need to be answered, such as how to structure this kind of integration with respect to students, teachers, languages and curricula; how to support and build on students' language and culture; and how to develop and sustain a multicultural and multilingual community of learning. The task they are assuming is ambitious. If they are successful, their experiment will serve as a model of educational excellence for all children.

While this vision may not be appropriate for all schools, it does exemplify what can happen if educators are given the chance to adapt for their own purposes the conceptual and practical principles underlying Cheche Konnen. No two adaptations will be exactly alike. As we have tried to communicate in this Handbook, collaborative scientific inquiry takes many forms. It can range from an investigation that lasts a few months, as happened in the Salt-study, to a year-long investigation, as happened in the Water Taste Test and Kindergarten Weather Study, and it can be observational, experimental, descriptive or analytic in nature.

As with any innovation, teachers and administrators must appropriate—or come to own—the Cheche Konnen approach. Each classroom and school interested in implementing collaborative scientific inquiry must create its own vision, adapting and even rethinking Cheche Konnen to fit its specific educational goals and needs. For some, the vision may be doing collaborative scientific inquiry within a single classroom; for others, the vision may be larger. Regardless, it should be approached by all as a process of growth and reflection.

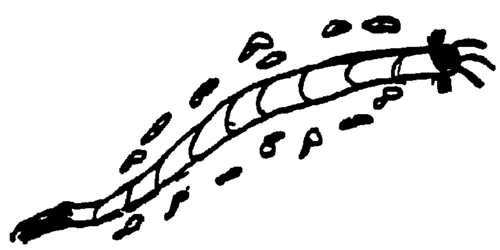
Margin Notes

ILLUSTRATIONS AND STUDENT WORK SAMPLES

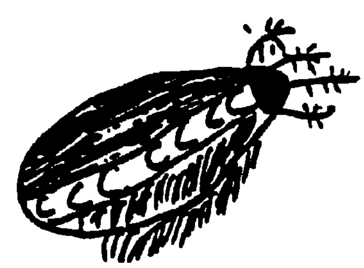
Figure 1: A student's report from the Field Guide created by the basic skills class.

Esto es lo que escribi sobre estos animales. (This is what I wrote about these animals.)

Este es un gusano que se mira sin el microscopeo. Es un animal pequeño que se mueve y es largo. El animal es de color rojo. Hay cosas pequeñas moviendo rapido cerca del animal. (This is a worm which is looked at without a microscope. It is a small animal that moves and is long. The animal is red. There are things moving rapidly near the animal.)



Este animal se mira sin el microscopeo. Se mira como puntos. Es un animal pequeño negro y esta moviendo muy rapido. (This animal may be seen without a microscope. They look like dots. It is a small black animal and it moves very fast.)



Estos son unos animales pequeños que se miran sin el microscopeo. Se ven como puntos estos animalitos se mueven muy rapido. (These are small animals that may be seen without a microscope. They look like dots and these little animals move very fast.)

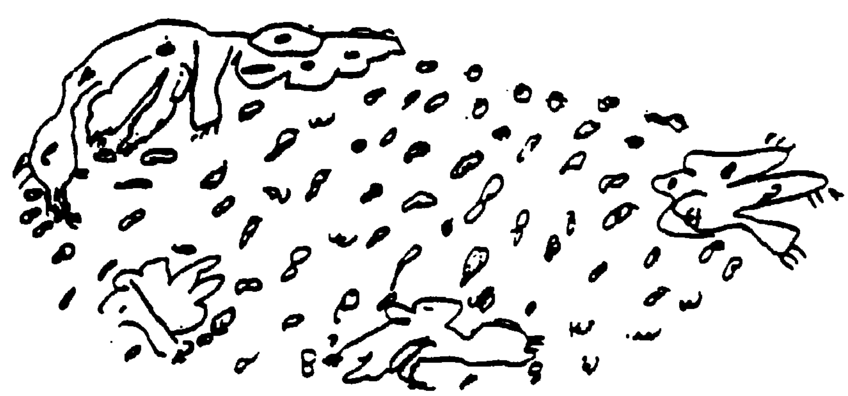


Figure 2: A student's report on temperature from the Field Guide.

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.

Figure 3: Salt questionnaire from the 7-8 grade salt study.

Wi Non

1. Eske ou manje potato chips souvan?
   Do you eat potato chips a lot?____________
2. Eske ou mete sel nan manje kwit anvan ou goute li?
   Do you put salt on a cooked food before you taste it?____________
3. Eske out mete andwi ak sel ansam nan manje?
   Do you put salt and sausage in food?____________
4. Eske ou manje pistach sale?
   Do you eat salty peanuts?____________
5. Eske ou konn manje manje sale?
   Do you eat salty food?____________
6. Eske ou manje janbon?
   Do you eat ham?____________
7. Eske ou manje vyann kochon sale?
   Do you eat meal salted porc?____________
8. Eske ou manje bekon?
   Do you eat bacon?____________
9. Eske ou manje sel kri?
   Do you eat plain salt?____________
10. Eske ou mete sel nan manba le ou ap manje-l?
    Do you put salt on peanut butter when you are eating it?____________
11. Eske ou manje aranso (aranseLmori)?
    Do you eat salted fish?____________
12. Eske ou manje sereyal?
    Do you eat cereal?____________

Please use our equipment to answer these questions:
Sèvi avèk zouti nou yo pou reponn kestyon sa yo:

1. Konbyen ou peze?
   What is your weight?____________
2. Ki wote ou?
   What is your weight?____________
3. Ki laj ou?
   How old are you?____________
4. Konbyen tansyon ou ye?
   What is your blood pressure?____________
5. Konbyen batman ke ou ye?
   What is your pulse?____________

Optional: (Reponn sa vo si ou vle:)

Name____________ Room Number ____________

Figure 4: Data collected for the 7–8 grade salt study, showing height, weight, age, number of positive responses to salt questionnaire, and height and weight percentiles.

	Wotè	Pis	Aceo	W	Wr		Pwio	
PERROT	5 pous	97	14 x	[illegible] x	14%	60	[illegible]	97
[illegible]	5 2 pous	[illegible]	13 x	9	[illegible]	6[illegible]	41[illegible]	[illegible]4
[illegible]	5 3 pous	[illegible]	13 x	0	[illegible]	63	[illegible]	[illegible]
[illegible]	5 pous	[illegible]	13 x	6	35%	60	[illegible]	[illegible]
[illegible]	4-11 pous	[illegible]	13 x	10	25%	59	[illegible]	90
[illegible]	[illegible] pous	99	14 x	0 +	50%	57	[illegible]	[illegible]
[illegible]	4-10 pous	86	12 x	0	31%	[illegible]	[illegible]	[illegible]
[illegible]	4-11 pous	128	12 x	6	16%	50	[illegible]	123
[illegible]	4-11 pous	96	12 +	3	53%	59	[illegible]	96
[illegible] M	5-2 pous	134	13 x	3	50%	62	97%	137
[illegible]	5-4 pous	132	13 +	0 +	58%	64	80%	132
[illegible]	5-3 pous	132	13 +	4	44%	63	80%	132
MARK[illegible]	4-8 pous	33	14 +	9	50%	56	50%	33
[illegible]	5-3 pous	103	14 +	6	39%	63	34%	103
[illegible]	5 pounds	99	13 x	[illegible]	35%	60	45%	[illegible]
[illegible]	4-11 pous	86	12 x	[illegible]	25%	59	[illegible]	[illegible]
[illegible]	5-4 pous	152	14 +	[illegible]	59%	64	[illegible]	152
[illegible]	5-2 pous	162	13 x	0 x	31%	62	85%	162
[illegible]	5-1 pous	91	12 x	6	59%	61	34%	91
[illegible]	5-1 pous	110	13 x	[illegible]	45%	61	70%	110
[illegible]	5-3 pous	102	12 x	0 x	44%	63	33%	102
[illegible]	5-3 pous	138	12 x		67%	63	95%	138
[illegible]	5-6 pous	115	14	[illegible]	75%	66	[illegible]	115
[illegible]	5 pous	114	12 x	[illegible]	5%	60	73%	114
[illegible]	5-2 pous	106	12	5	50%	62	57%	106

BEST COPY AVAILABLE

Notes

1. Page 9. In addition to money, there are, of course, other ways of recognizing teachers' efforts. For example, they can be asked to share what they have been doing with their colleagues; their efforts can be acknowledged by the school board; parents can sponsor a luncheon or supper to thank them for their work.

2. Page 15. We note briefly that not all inquiries depend on hypotheses; some are more observational in nature in order to build up a knowledge base from which more experimental inquiries can then be generated.

3. Page 16. Again, we wish to make the point that in the case of more observational or descriptive studies, students must also determine an appropriate research design or methodology.

Contacts and Materials Available

The following is a list of contacts in alphabetical order who can provide information about the Chech : Konnen project and field test.

Charlene Rivera
Director, Innovative Approaches Research Project
Development Associates Inc.
1730 N. Lynn Street
Arlington, VA 22209-2023
telephone 703 276-0677

Ann S. Rosebery & Beth Warren
Co-Principal Investigators, Cheche Konnen
Technical Education Research Center
2067 Massachusetts Avenue
Cambridge, MA 02140
telephone 617 547-0430

The following project reports are available by contacting Drs. Rivera, Rosebery or Warren.

Rosebery, A., Warren, B. & Conant, F. (February, 1990a). *Making sense of science in language minority classrooms.* (Technical Report No. 7306). Cambridge, MA: Bolt, Beranek & Newman.

Explores, through an analysis of students' writing, how a group of language minority students, many of whom had never studied science before and some of whom had had very little schooling of any kind, began to acquire scientific ways of thinking, talking, and writing.

Rosebery, A., Warren, B., & Conant, F. (April, 1990b). *Cheche Konnen investigations. 1988–1989; 1989–1990.* Cambridge, MA: Bolt, Beranek, & Newman.

Outlines investigations conducted during the Cheche Konnen field test.

Rosebery, A., Warren, B., & Conant, F. (July, 1990c). *Appropriating scientific discourse: Findings from language minority classrooms.* (Technical Report No. 7353). Cambridge, MA: Bolt, Beranek & Newman.

Reports the results of an evaluation of students' learning, examining the extent to which students began to acquire scientific ways of talking and reasoning.

Warren, B., Rosebery, A., & Conant, F. (December, 1989a). *Cheche Konnen: Science and literacy in language minority classrooms.* (Technical Report No. 7305). Cambridge, MA: Bolt, Beranek & Newman.

Analyzes the ways in which the Cheche Konnen model was interpreted in two language minority classrooms and the effects of these interpretations on science and literacy practices in those classrooms.

Warren, B., Rosebery, A., & Conant, F. (March, 1990b). *Teaching teachers to do science in language minority classrooms: A Teacher Training Plan.* Cambridge, MA: Bolt, Beranek & Newman.

Outlines a plan for training teachers to use collaborative scientific inquiry in language minority classrooms.

Warren, B., Rosebery, A., Conant, F., & Hudicourt-Barnes, J. (1990). *Cheche Konnen: Collaborative Scientific Inquiry in Language Minority Classrooms. (Final Technical Report, Innnovative Approaches Research Project)*; Arlington, VA: Development Associates.

Bibliography and Works Cited

American Association for the Advancement of Science. (1989). *Science for All Americans*. Washington: AAAS.

Au, K. (1980). Participation structures in a reading lesson with Hawaiian children: Analysis of a culturally appropriate instructional event. *Anthropology and Education Quarterly, 11* (2), 91–115.

Bakhtin, M. (1981). *The dialogic imagination*. Austin: University of Texas.

Barnes, D. & Todd, F. (1977). Talk in small learning groups: Analysis of strategies. In C. Adelman (Ed.), *Uttering, muttering: Collecting, using and reporting talk for social and educational research*. London: Grant McIntyre.

Barnes, J., Solo, L, Rosebery, A.S. & Warren, B. (1990). *Interpreting educational innovation: A case study of school-researcher collaboration*. Paper presented at the meeting of the American Educational Research Association, Boston, MA.

Brown, A. & Palinscar, A.M. (in press). Guided, cooperative learning and individual knowledge acquisition. In L.B. Resnick (Ed.), *Cognition and instruction: Issues and agendas*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Cazden, C.B. (1989). *Vygotsky and Bakhtin: From word to utterance and voice*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Cazden, C.B., John, V. & Hymes, D. (Eds.) (1972). *Functions of language in the classroom*. New York: Teachers College Press.

Cazden, C.B. & Legget, E.L. (1981). Culturally responsive education: Recommendations for achieving Lau Remedies II. In H.T. Trueba, G.P. Guthrie, & K. Au (Eds.) *Culture and the Bilingual Classroom Ethnography*. Rowley, MA: Newbury House Publishers, Inc.

Cochran, C. (1989). *Strategies for involving LEP students in the all-English medium classroom: A cooperative learning approach*. Washington, DC: National Clearinghouse for Bilingual Education.

De La Rosa, D. & Maw, C. (1990). *Hispanic education: A statistical portrait 1990*. Washington, DC: National Council of La Raza.

Duckworth, E. (1987, November). Teaching as research. *Harvard Educational Review, 56* (4), 481–495.

Frederiksen, J.R. & Collins, A. (1989). A systems approach to educational testing. *Educational Researcher, 18* (9), 27–32.

Gardner, H. (1988). Assessment in context: The alternative to standardized testing.

Gee, J.P. (1989). *What is literacy?* (Technical Report No. 2). Newton, MA: The Literacies Institute.

Hatano, G. (1981). Cognitive consequences of practice in culture specific procedural skills. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 4*, 15–18.

Heath, S.B. (1983). *Ways with words: Language, life, and work in communities and classrooms.* New York: Cambridge University Press.

Inagaki, K. & Hatano, G. (1983). Collective scientific discovery by young children. *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 5,* Number 1.

Jacob, E. & Mattson, B. (1987). *Cooperative learning with limited-English-proficient students.* Report prepared for the Office of Educational Research and Improvement, U.S. Department of Education by the Center for Language Education and Research. Washington, DC: Center for Applied Linguistics.

Kagan, S. (1986). Cooperative learning and sociocultural factors in schooling. In Bilingual Education Office, California State Department of Education (Ed). *Beyond language: Social and cultural factors in schooling language minority students* (pp. 231–298). Los Angeles: Evaluation, Dissemination and Assessment Center, California State University.

Lara, J. & Hoffman, E. (1990). *School success for limited English proficient students: The challenge and state response.* Washington, DC: Council of Chief State School Officers.

Latour, B. (1987). *Science in action.* Cambridge: Harvard University Press.

Latour, B. & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts.* Princeton, NJ: Princeton University Press

Lave, J. (in preparation). *Tailored learning: Apprenticeship and everyday practice among craftsmen in West Africa.*

Longino, H. (1990). *Science as social knowledge.* Princeton: Princeton University Press.

Massachusetts Institute for Technology (1990). *Education that works: An action plan for the education of minorities.* Cambridge, MA: MIT.

McKnight, C. et al. (1987). *The underachieving curriculum: Assessing U.S. school mathematics from an international perspective.* Champaign, IL: Stipes.

McPartland, J. & Slavin, R. (1990). *Policy perspectives: Increasing achievement of at-risk students at each grade level.* Washington, DC: US Government Printing Office.

Melendez, S.E. (1989, February). *Linguistic minorities in science and technology.* Paper presented to the Mathematics, Science and Minorities K-6 Project, Mid-Atlantic Equity Center, Prince George's County, MD.

Moll, L., Vélez-Ibáñez, C. & Greenberg, J. (1990). *Community knowledge and classroom practice: Combining resources for literacy instruction* (Final Technical Report, Innovative Approaches Research Project). Arlington, VA: Development Associates, Inc.

Moll, L., Vélez-Ibáñez, C., Greenberg, J., Andrade, R., Dworin, J., Saavedra, E. & Whitmore, K. (1990). *Community knowledge and classroom practice: Combining resources for literacy instruction.* A Handbook for Teachers and Planners from the Innovative Approaches Research Project. Arlington, VA: Development Associates, Inc.

Mullis, I. & Jenkins, L. (1988). *The science report card*. Princeton: National Assessment of Educational Progress.

Oakes, J. (1990). *Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science*. Santa Monica, CA: Rand Corporation.

Office of Technology Assessment. (1987). *Trends and status of computers in schools: Use in Chapter 1 programs and use with limited-English-proficient students*. Washington, DC.

Ortiz, A.A., Wilkinson, C.Y. & Bergman, A.H. (1990, April). *Assessment and intervention model for the bilingual exceptional student: An innovative approaches research project*. Paper presented at the meeting of the American Educational Research Association, Boston, MA.

Ortiz, A.A., Wilkinson, C.Y. & Robertson-Courtney, P. (1990). *AIM for the BESt: Assessment and intervention model for the bilingual exceptional student*. A Handbook for Teachers and Planners from the Innovative Approaches Research Project. Arlington, VA: Development Associates, Inc.

Ortiz, A.A., Wilkinson, C.Y., Robertson-Courtney, P. & Bergman, A. (1990). *AIM for the BESt: Assessment and intervention model for the bilingual exceptional student* (Final Technical Report, Innovative Approaches Research Project). Arlington, VA: Development Associates, Inc.

Philips, S. (1974). *The invisible culture: Communication in classroom and community in the Warm Springs Reservation*. New York: Longman.

Resnick, L. (1989). Treating mathematics as an ill-structured discipline. In R. Charles & E. Silver (Eds.), *The teaching and assessing of mathematical problem solving*, pp. 32–60. Reston, VA: National Council of Teachers of Mathematics.

Rivera, C. (1990). *IARP project, purposes, and approaches* (Final Performance Report, Innovative Approaches Research Project). Arlington, VA: Development Associates, Inc.

Rivera, C. & Zehler, A. (1990). *Assuring the academic success of language minority students: Collaboration in teaching and learning*. Arlington, VA: Development Associates, Inc.

Robledo, C., Cárdenas, J., García, Y., Montemayor, A., Ramos, M., Supik, J. & Villarreal, A. (1990). *Partners for Valued Youth: Dropout prevention strategies for at-risk language minority students* (Final Technical Report, Innovative Approaches Research Project). Arlington, VA: Development Associates, Inc.

Robledo, C., Cárdenas, J., García, Y., Montemayor, A., Ramos, M., Supik, J. & Villarreal, A. (1990). *Partners for Valued Youth: Dropout prevention strategies for at-risk language minority students*. A Handbook for Teachers and Planners from the Innovative Approaches Research Project. Arlington, VA: Development Associates, Inc.

Rosebery, A., Warren, B. & Conant, F. (1989a). *Cheche Konnen formative evaluation report: Teaching teachers to teach science in bilingual classrooms*. Cambridge, MA: Bolt, Beranek & Newman.

Rosebery, A., Warren, B. & Conant, F. (February, 1990a). *Making sense of science in language minority classrooms.* (Technical Report No. 7306). Cambridge, MA: Bolt, Beranek & Newman.

Rosebery, A., Warren, B. & Conant, F. (April, 1990b). *Cheche Konnen investigations: 1988–1989; 1989–1990.* Cambridge, MA: Bolt, Beranek & Newman.

Rosebery, A. Warren, B. & Conant, F. (July, 1990c). *Appropriating scientific discourse: Findings from language minority classrooms.* (Technical Report No. 7353). Cambridge, MA: Bolt, Beranek & Newman.

Rosebery, A., Warren, B., Conant, F. & Hudicourt-Barnes, J. (1990). *Cheche Konnen: Collaborative scientific inquiry in language minority classrooms.* A handbook for teachers and planners from the Innovative Approaches Research Project. Arlington, VA: Development Associates, Inc.

Schoenfeld, A. (in press). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. To appear in D. Grouws (Ed.), *Handbook for Research on Mathematics Teaching and Learning*. New York: MacMillan.

Solis, A. (1988). Planning for cooperative learning. *Classroom practices bulletin*. *2*(1), Southwest Educational Development Laboratory, 1-3.

Steen, L. (1987). Mathematics education: A predictor of scientific competitiveness. *Science*, 237, 251–252 & 302.

Tikunoff, W. J., et al. (1981). *Review of the literature for a descriptive study of significant bilingual instructional features*. San Francisco, CA: Far West Laboratory for Educational Research and Development.

U.S. Equal Employment Opportunity Commission (1986). *Project 2000: Job and training opportunities for minorities and women*. Washington, DC: U.S. Equal Employment Opportunity Commission.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge: Harvard University Press.

Warren, B., Rosebery, A. S. & Conant, F. R. (1989). *Cheche Konnen: Science and literacy* (Technical Report No. 7305). Cambridge, MA: Bolt, Beranek & Newman.

Warren, B., Rosebery, A. & Conant, F. (1990). *Cheche Konnen: Collaborative scientific inquiry in language minority classrooms* (Final Technical Report, Innovative Approaches Research Project). Arlington, VA: Development Associates, Inc.

Warren, B., Rosebery, A. & Conant, F. (1990). *Making sense of science in language minority classrooms*. (Technical Report No. 7306). Cambridge, MA: Bolt, Beranek & Newman.

Warren, B., Rosebery, A. & Conant, F. (March, 1990). *Teaching teachers to do science in language minority classrooms: A teacher training plan*. Cambridge, MA: Bolt, Beranek & Newman.