The Inclusive Classroom

Teaching Mathematics and Science to English-Language Learners

IT'S JUST GOOD TEACHING

Northwest Regional Educational Laboratory

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By Denise Jarrett
Mathematics and Science Education Center

November 1999

Northwest Regional Educational Laboratory

Table of Contents

Preface

LANGUAGE-MINORITY STUDENTS ARE THE FASTEST GROWING group in Northwest schools—their numbers more than doubling in Alaska, Idaho, Montana, Oregon, and Washington this decade. At the same time, mathematics and science education has been undergoing major reforms that have raised the expectations for all students. These reforms, with an emphasis on learning challenging content and developing depth of understanding through problem solving and inquiry, place high demands on students' communication skills. To enable English-language learners to participate meaningfully in the academic discourse and activities that are necessary to achieve the mathematics and science standards, teachers must help them to develop language skills that go beyond mere social fluency.

Fortunately, research indicates that principles of standards-based teaching and second-language acquisition strategies are similar. The active learning central to problem solving and inquiry also promotes the development of students' communication skills. Today's inclusive classrooms provide both challenges and rich learning opportunities for teachers and students. *Teaching Mathematics and Science to English-Language Learners* offers ideas about how to link standards-based teaching strategies with techniques from the field of second-language acquisition.

This publication is part of the Northwest Regional Educational Laboratory's series, It's Just Good Teaching. This series of publications and videos offers teachers research-based instructional strategies with real-life examples from Northwest classrooms. *Teaching Mathematics and Science to English-Language Learners* is one of a three-issue focus on the diverse needs of students in inclusive classrooms. Two other publications in the series address strategies for teaching students with learning disabilities and gifted students. We hope readers will find this publication useful in their efforts to provide all students with high-quality mathematics and science learning experiences.

Kit Peixotto
Director
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Introduction

LEARNING AN ADDITIONAL LANGUAGE IS VERY MUCH LIKE learning a first language, some researchers theorize. They contend that the brain may be "hard wired" or programmed to learn language, so that, regardless of whether it's the first or subsequent language being learned, the process of acquiring it is similar. Therefore, much like a toddler will learn her first language in the context of daily encounters with the real world and interactions with other people, so will a student learn a second language best when he can learn it in an authentic and interactive environment (Radford, Netten, & Duquette, 1997).

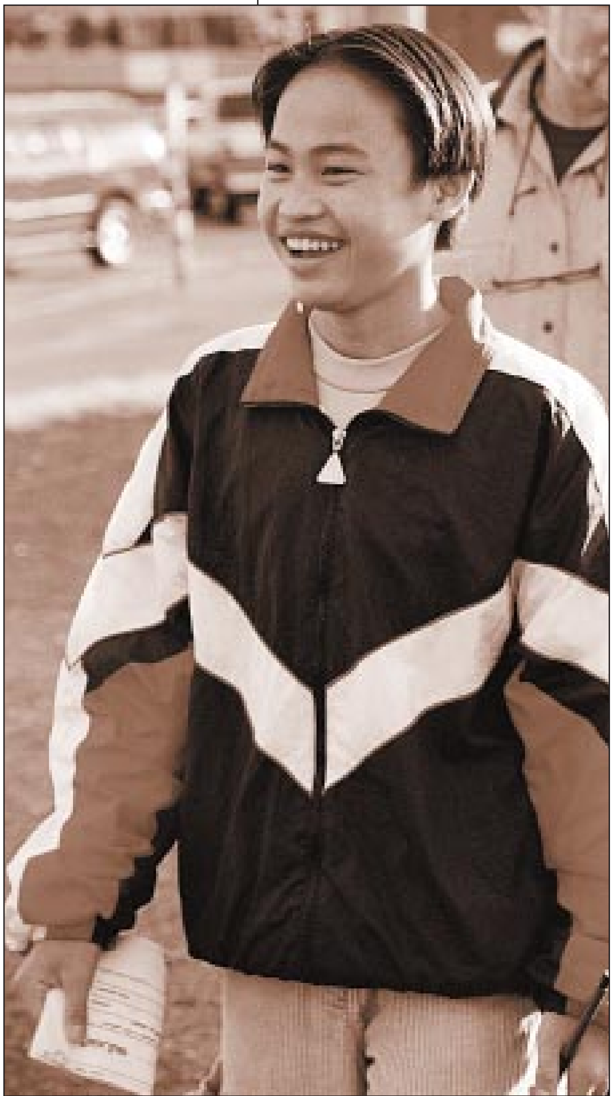
> THE ABILITY TO SPEAK ENGLISH AND A SECOND LANGUAGE, COMBINED WITH STRONG SKILLS IN MATHEMATICS AND SCIENCE, WILL PROVIDE UNLIMITED OPPORTUNITIES ....
>
> —American Association for the Advancement of Science (1998)

Social and academic languages. Two kinds of language conventions take place in the classroom: social language and academic language. Social language conventions are highly contextual, enabling language-minority students to infer meaning and interpret visual cues and body language. Meanings in social discourse are built collaboratively. On the other hand, academic language is more abstract and common words can take on specialized meanings. In academic discourse, students are often individually responsible for constructing meanings and must rely on their own understanding of both the language and concepts involved. They are both important to students' learning and social development, but, while students can be relatively proficient in social language, they must be explicitly taught to use academic language (Kang & Pham, 1995; Laplante, 1997; Lee & Fradd, 1996).

Role of home languages. Much debate has centered on which language should be used as the primary language of instruction, English or the child's home language. Research shows that students' home languages can play an important role in their science and math learning, whether or not the teacher speaks these languages. When students are allowed to use their home language in the classroom, their academic performance as well as English-language development often improves (Kang & Pham, 1995; Latham, 1998). It can be especially helpful to younger students to use their home language in academic learning. This can enable them to build a foundation of math and science concepts before entering higher grades where language becomes more "decontextualized and cognitively demanding" (Cummins, 1992, as cited by Rupp, 1992).

Research shows that "skills in content areas like mathematics and social studies, once learned in the first language, are retained when instruction shifts to the second language," says James Crawford (1995).

A 1999 conference organized by the U.S. Department of Education's National Educational Research Policy and Priorities Board and the Office of Bilingual Education and Minority Language Affairs surveyed successful research-based practices for language-minority students. It concluded that students achieve slightly better in mathematics and reading when their home languages are incorporated into instructional programs. The research board recommended that broad instructional approaches be used for teaching English-language learners (Viadero, 1999).



Understanding the Specialized Languages of Mathematics and Science

Mathematics and science classrooms based on inquiry and problem solving hold special promise and challenge for language-minority students. Scientific inquiry and mathematical problem solving are suffused with talk: questioning, describing, explaining, hypothesizing, debating, clarifying, elaborating, and verifying and sharing results. While the language demands are significant, the potential is also strong that students will learn important English-language skills as well as science and math content (Buxton, 1998; Crawford, 1995; Kang & Pham, 1995; Kessler, Quinn, & Fathman, 1992; Laplante, 1997).

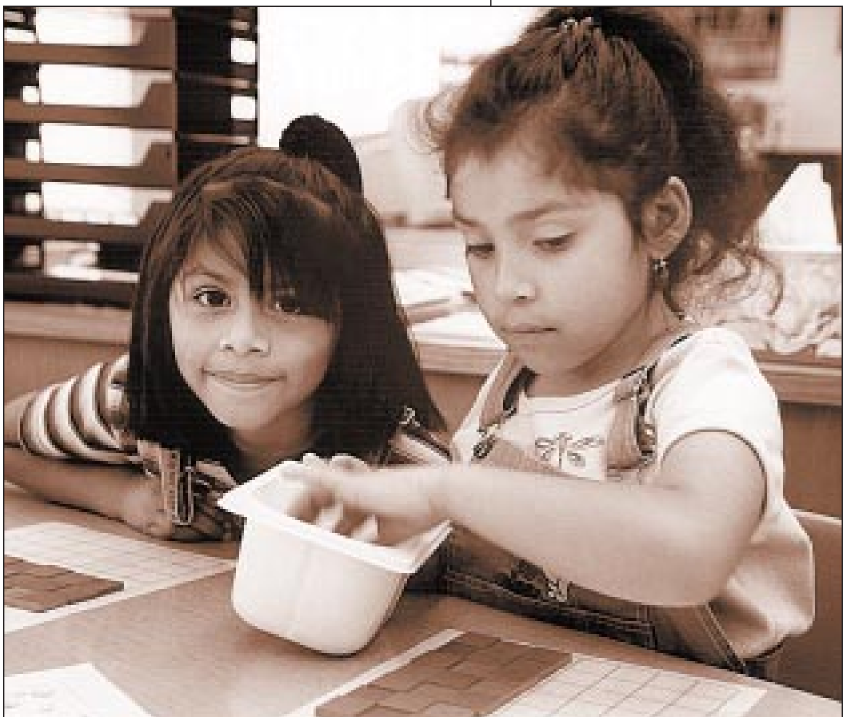
> Teachers need to help students ... communicate effectively in the formal register of mathematics.
>
> —Kang & Pham (1995)

Traditionally, mathematics has been thought of as an area with minimal language demands. In fact, mathematics and language are intricately connected—language facilitates mathematical thinking (Dale & Cuevas, 1992). Today's emphasis on problem solving and communication in mathematics means, more than ever, that students must be skilled in using at least the basic language of mathematics. The language of mathematics includes specialized vocabulary and discourse features (Kang & Pham, 1995). It also incorporates "everyday vocabulary that takes on a different meaning in mathematics," like *equal, rational, irrational, column,* and *table* (Dale & Cuevas, 1992).

Mathematical operations can be signaled in many different ways, posing additional challenges for language-minority students. For example, addition can be signaled with the words: *add, plus, combine, and, sum, increased by.* Some mathematical symbols used in other countries differ from how they are used in the United States. For example, the comma may be used to separate whole numbers from decimal parts (functioning as the decimal point does in this country). On the other hand, a decimal point may be used as the comma is here, to separate hundreds from thousands, hundred thousands from millions, and so on (Dale & Cuevas, 1992).

Language-minority students may attempt to read and write mathematical sentences in the same way that they read and write standard narrative text. In other words, they may try to translate word-for-word between a mathematical concept expressed in words and the concept expressed in symbols. However, the way a mathematical concept is expressed in words often differs in its order from the way the concept is expressed in symbols. A linear, one-to-one translation is often not possible. Dale and Cuevas (1992) offer as examples the phrase *eight divided by two,* which might be incorrectly translated to $8\overline{)2}$ rather than $2\overline{)8}$, or the algebraic phrase, *the number* a *is five less than the number* b, which the student may mistakenly restate as $a=5-b$, when it should be $a=b-5$.

Science, on the other hand, is recognized as a highly communicative discipline, where language is central to the collaborative nature of scientific discourse. However, there is an established way of "talking science." Language conventions are evident in the way we argue or debate in science; the way we offer hypotheses or communicate inferences; the way we negotiate meaning by questioning, paraphrasing, or elaborating during scientific discourse (Laplante, 1997).



Students who are learning English as a new language, especially younger students, often have difficulty interpreting the meaning of logical connectors in mathematics and science discourse. Logical connectors are words or phrases, such as the words *if, because, however,* and *consequently,* that signal a logical relationship between parts of a text. In mathematics and science, logical connectors signal similarity or contradiction; cause and effect; reason and result; and chronological or logical sequence. Students who have trouble with logical connectors in a mathematical or scientific problem may be able to solve it when it is restated using a declarative sentence (Dale & Cuevas, 1992; Kessler, et al., 1992).

The section, "Linking Second-Language Strategies with Content Instruction," will highlight techniques teachers can use to help language-minority students develop skills in using the specialized languages of mathematics and science.

Shared Past Draws Teacher, Students Together

Clark Middle School, Anchorage, Alaska

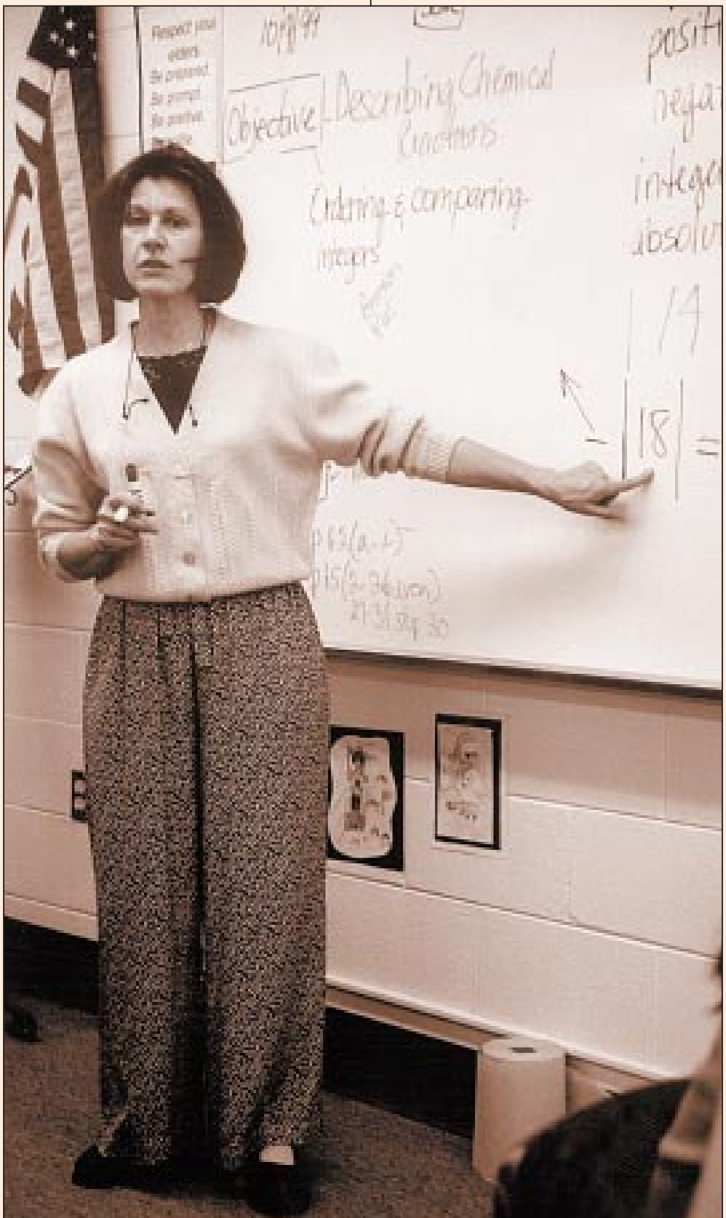
Sometimes we don't realize what draws us to do a particular thing until someone asks. Then, in our attempt to explain, we see with surprise that it makes perfect sense. Such seems to be the case with teacher Mary Ellen Kisling Darling when asked about her affinity for teaching language-minority students.

Her background provides the clue. Raised in the mid*west by parents who immigrated from Czechoslovakia, Darling spoke only Czech as a girl. As a young adult, she moved to Dillingham, a fishing village in Alaska, where she lived for 25 years, teaching Alaska Native youngsters about Western ideas in science. Not long ago, she and her family left the village, moving to Alaska's most urban city, Anchorage. She applied to one school only: Clark Middle School, which has one of the highest percentages of language-minority students in the district. When asked, she concedes that a common thread may connect her to these young people from distant villages, islands, and countries. As she speaks, her own personal history takes shape.*

There's something in my history that's dark. My mother's family came to the United States from Czechoslovakia because they were running away from persecution. My father's family were poor Czech farmers. Both families settled in the Midwest. My parents started as farmers, but they were too poor, so we moved to the city, a suburb of Milwaukee, and my dad got a job as a butcher in a factory. The community was Polish, Czech, and German. I spoke Czech until I was in kindergarten. Czech continued to be our primary language at home until I was in about third or fourth grade, when my parents were scolded by teachers for not speaking more English with us.

Now that my brothers and sisters and I are older, we know that there's something unique about our family. We're bonded by blood. We all had the same beginnings. But we grew out of our language, we've forgotten it, and we regret that. It is a really rich language, but nobody encouraged us to keep speaking Czech. I wish somebody would have said, "Always remember it."

As a youth, Darling read in English to her parents and helped her dad with his spelling when he began to write letters in English. After high school, she went to college and earned a nursing degree. The Vietnam War was in full swing. She participated in peace marches and demonstrations. She and her brother even made plans to emigrate to Canada. Though her brother's application was accepted by Canadian immigration, her's wasn't, so the two stayed in the U.S. But Darling's wanderlust was aroused.



I always wanted to go to Alaska. I knew I wanted to feel special. I didn't feel special in the city and I wanted that so badly. So after college I hitchhiked across the country but only made it as far as Colorado. But it was so beautiful I didn't mind staying. I ran a health food store and lived under a tarp until the snows came three months later. I called the Alaska Nursing Association and asked if they had any jobs, and they told me that there was an opening for a nurse in Dillingham. I took a train back home to Wisconsin and packed. My mother put $20 in my pocket and I flew to Alaska.

When I got off the plane in Dillingham, five men were there to greet me—there weren't that many available women in town! There were 800 people living there then; now there are 2,000. I worked as a nurse for about a year, but it was very frustrating. I got into a lot of trouble because I asked questions. Patients weren't supposed to ask questions, either, and that was especially difficult for Alaska Natives who weren't fluent in English. This became a big issue for me. I began to want to work where the approach was preventative, not curative. I decided I wanted to be a teacher. I went to Anchorage and got my teaching certificate, then moved back to Dillingham.

I wanted to teach those village kids. I felt strongly that they had a right to information that would help them. I wanted to make education practical for them because the kids needed survival skills. I taught them how to use tools, to make a perfect square so that they could make foundations for their homes; I taught them applied mathematics. We went on survival trips. I taught several students to be nurses' aides, and three out of seven became village health workers.

After living in Dillingham for years, Darling and her husband, William, 51, decided to move to Anchorage. They thought it might be good for their children, Evan and Brook, to experience life in a larger city. The urban lifestyle has introduced their children to new and valuable experiences, but for Darling, city life now seems foreign to her.

I wouldn't have moved but Bill said, "Change is good." Evan and Brook were very rural children at the time. They thought the world revolved around them because everyone knew them and everyone cared about them. But they weren't into basketball or wrestling, which were very popular sports in Dillingham. My son was a good skier, so we moved to Anchorage to see what he could accomplish with that. He did very well. Brook said she wanted to play the cello, and now she plays with the school orchestra. I wouldn't have known these things about them. It's almost scary. But I don't feel like I belong in the city. Not yet. There are things that scare me about it, like the fast pace.

I don't do things fast, but that's probably advantageous for my bilingual kids. I don't make any other allowances for them. They have to learn the same things as everyone else. I've been there. I know it's hard. I'm grateful that teachers didn't give up on me and expected me to do well. They also need to keep up their language and culture; I think they'll have a richer life if they do. They'll have more opportunities. They can enjoy more things. Whereas I can only relate to one culture, they can enjoy a Thai dance one moment and rap music the next.

I think these kids are hearing a different message than I did when I was in school. Clark is one of the most unique schools in the district. I'm choosing to be here. I'm addicted to those kids. The baggage some of them carry is incredible to me. Baggage that would make me immobile, but they live with that and come to school every day. I believe I do make a difference in the children's lives, if only for six hours a day.

Darling has certainly made a difference in Yagga's life. Yagga moved with her family from West Africa to Alaska two years ago. Her parents are very eager for her to do well in her new school. But, at the beginning of the school year, Yagga told Darling not to call on her because she couldn't speak English very well. "Guess what, I pick on people!" Darling told her good-naturedly, adding, "You won't get any better if you don't try." Today, Yagga seems to be thriving under Darling's caring but rigorous tutelage.

Yagga didn't want to talk in class, and she wanted to sit as close to me as possible for reassurance. She was scared in the beginning to sit next to boys because she didn't want to be teased. She thought she was dumb. She's not, she's smart. She works really hard. I helped her during lunch and after school. It wasn't long before she was joining in class discussions. Now, she sits next to a boy and isn't scared at all. She's getting really savvy. We were doing a unit on women in science as part of our study of chemistry and the periodic table, and we read about Marie Curie, who won two Nobel peace prizes for her work with radium, and Maria Goeppert-Mayer, a Nobel Laureate in Physics. Yagga wrote in a paper about how awesome these women were for not giving up. She's also driven. I don't know what drives her. Want to hear what she's doing now? She's campaigning for the position of recorder on a schoolwide student advisory board!

Darling's exclamation of pride is the surest sound of someone whose inner compass has steered them right. In the company of young people from diverse homelands, Darling not only guides them through encounters with Western ideas in mathematics and science, but enlivens the journey with humor and wisdom that springs from a common past.

Linking Second-Language Strategies with Content Instruction

MANY OF THE TEACHING APPROACHES SUGGESTED BELOW are identified in current mathematics and science education reform as effective instruction for all students. By linking these core instructional strategies with techniques from the field of second-language acquisition, teachers can target the specific needs of language-minority students.

Thematic Instruction

By organizing key concepts, or big ideas, into theme-based units, teachers can create extended learning experiences that give students more time to become proficient with the language used to discuss and explore those larger concepts (Anstrom & Lynch, 1998). To help language-minority students connect their prior knowledge and experiences with new information presented in the curriculum, teachers will want to place thematic units in the context of students' everyday lives (Kessler, et al., 1992; Lee, Fradd, & Sutman, 1995). This can be achieved by including real-world applications of key concepts; presenting ideas and organizing activities in the context of students' home cultures; and by encouraging students to talk about their prior experiences and knowledge concerning the theme. Students who find it difficult to enter into classroom conversations may need, at times, to draw on their informal language skills and personal experiences to express their understanding (Ballenger, 1996).

> THE PARALLELS OR LINKS BETWEEN SCIENCE LEARNING AND SECOND-LANGUAGE LEARNING ARE REMARKABLY STRONG.
>
> —Kessler, Quinn, & Fathman (1992)

Cooperative Learning

In cooperative learning, students use language related to the task while conversing, collaborating, and tutoring one another. By using their second-language skills in authentic discourse, students are exposed to complex language structures and have opportunities to refine their communication skills by negotiating meaning through talk. By articulating their problem-solving strategies and reasoning within a group, students can improve both their language and reasoning skills (Kang & Pham, 1995; Spanos, 1992). In cooperative learning, teachers will want to ensure that tasks are structured so that language-minority students can contribute meaningfully to the group effort, whatever their level of English proficiency (Kang & Pham, 1995).

Inquiry and Problem Solving

Language-minority students can develop inquiry-based and problem-solving strategies before they are proficient in English. As previously mentioned, problem-solving and inquiry approaches to mathematics and science can enhance students' language acquisition as well as their content knowledge (Dalton & Sison, 1995). Inquiry, problem solving, and second-language acquisition often progress from concrete strategies to more abstract reasoning. Thus, as students move from concrete to more abstract content, their linguistic skills also progress in complexity, enhancing learning in both areas (Radford, et al., 1997).

In problem solving and inquiry, students need to know how to ask for repetition and meaning; to tell others what and how to do something; to verify and compare information; to participate in discussions and provide feedback; to report findings or a result; to express their opinion and explain their reasoning; and to summarize or draw conclusions. To facilitate this, teachers and English-proficient students can model these language skills as well as those for expressing agreement and disagreement (Kessler, et al., 1992).

Problem-solving and inquiry activities should be relevant to students' real-life experiences and prior knowledge. Activities should include the use of graphics, manipulatives, and other hands-on experiences to clarify and reinforce meaning. Students should have many opportunities to write reports, explanations, descriptions, their own word problems and problem-solving strategies, journal entries, and so on. When the objective of the inquiry or problem-solving task is targeting content—rather than vocabulary or some other aspect of language—teachers will want to give greater emphasis to *what* the child says or writes, and attend to grammatical or spelling errors secondarily (Buxton, 1998).

Scientific inquiry. Students who are new to the study of science may need to begin with explicit instruction and progress to more exploratory learning, gradually developing independent-learning skills. Students who don't know Western cultural rules for conducting science inquiry, such as cultural conventions of questioning, planning, hypothesizing, collecting and analyzing data, discussing, and constructing theories and explanations, may not be able to fully participate in classroom learning. Fradd and Lee (1999) explain:

> ... Delpit (1995) suggests that exploratory approaches may not be appropriate for students who do not know the rules for participating in open-ended tasks. For students unaware of the culturally-based rules for engaging in exploratory activities, what may appear to be egalitarian and democratic can, in reality, produce the opposite outcomes. Because the indirect nature of exploratory instruction makes it difficult for students to acquire participation rules on their own, exploration may limit, rather than enhance, students' opportunities to learn. Delpit (1995) believes that students unfamiliar with particular approaches may require explicit instruction in order to acquire skills for effective participation.

Students' cultural values and styles of interacting may differ from what's expected in an inquiry activity. Students may be more comfortable when classroom interactions resemble that of their home culture. For example, Fradd and Lee (1999) state:

> [T]he rules of science inquiry, including the use of empirical evidence, logical arguments, skepticism, questioning, and criticism, may be incongruent with the values and norms of cultures favoring social consensus, shared responsibility, emotional support, and respect for authority.

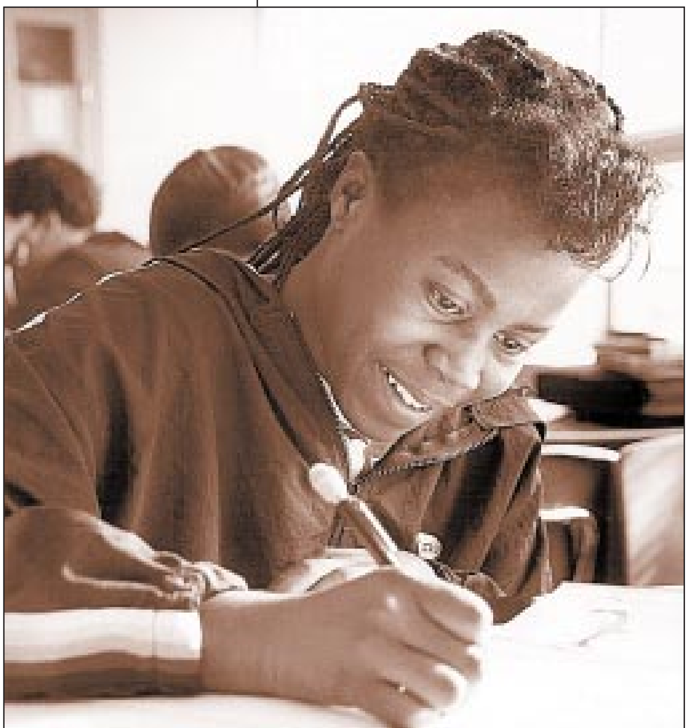
Some students may have difficulty using some language functions, such as reflecting, predicting, inferencing, and hypothesizing. Their prior experiences in school or at home may not have prepared them to ask probing questions or to plan their own investigations. Initially, some students may prefer that teachers tell and direct them, rather than to do their own "inquiring, exploring, and seeking alternative ways" (Lee & Fradd, 1998).

Nevertheless, from a language perspective, an inquiry approach has many benefits. Aspects of inquiry—such as discourse; questioning; investigating; observing, classifying and measuring objects and phenomena; and collecting and analyzing data—can create an environment favorable to second-language development (Laplante, 1997). The best approach, say Fradd and Lee (1999), integrates explicit instruction with exploratory learning in a complementary fashion to address individual student's needs. This requires a great deal of the teacher's own best judgment. Her decisions, however, must ensure that students progress beyond basic content knowledge, acquire inquiry strategies, and develop an understanding of important science concepts.

For example, to introduce students to an inquiry unit, teachers can present a new concept or problem with a demonstration, allowing students to listen and observe before having to communicate. During the demonstration, teachers can use concrete objects and actions to help students construct meaning. As a guide and follow-up to the demonstration, students can use a worksheet to help them develop relevant vocabulary as well as conceptual understanding. A class discussion can then follow (Fathman, Quinn, & Kessler, 1992; Kessler, et al., 1992). Later, for more interactive learning, students of varying English proficiency can gather into small groups to engage in an inquiry activity. The language-filled and interactive nature of small-group work creates an authentic context that reinforces language development as well as content learning. Students can tutor each other, offering tips on English-language usage as well as building on each other's understanding of science. Like professional scientists, students can solve problems and construct knowledge in a collaborative environment. As a follow-up to group activities, students can conduct individual investigations. Because language-minority students will vary in

their ability to communicate their findings, teachers can ask students to return to their small groups to discuss their individual investigations and select a group member to report back to the whole class (Anstrom & Lynch, 1998; Kessler, et al., 1992; Minicucci, 1996).

The language component of an inquiry unit might involve asking beginning-level English-speakers to follow simple action commands, identify the names of objects, answer yes/no questions, report results involving numbers or short answers, and read relatively easy words related to visuals or concrete objects. Intermediate-level English-speakers can be encouraged to talk about actions, objects, and pictures; to ask and answer basic questions; and to write and read aloud simple descriptions of what they have done or observed or short answers to questions. Students who are more advanced English-speakers can be guided to encourage less English-proficient students, peer tutoring them on content as well as vocabulary and grammar. They can follow detailed instructions, give explanations, ask and answer complex questions involving *how* and *why*, talk about abstract ideas, summarize, and express their opinions in writing (Kessler, et al., 1992).



Mathematical problem solving. To help students tackle the linguistic demands of mathematical problem solving, teachers can introduce a discussion about the vocabulary and situational context of the problem. This helps students to warm up to the linguistic and conceptual tasks and to attach personal meaning to the problem. Next, teachers can help students break down the problem into "natural grammatical phrases." This helps students to understand the meaning of the context and mathematical relationships expressed in the problem—a technique students can apply to future problems. Further, teachers can help students to derive meaning by providing visual cues such as graphic representation, physical gestures and role playing, and asking students to rephrase the problem in their own words. Working in pairs, students can then work the problem and provide a solution and explanation of their problem-solving strategies (Kaplan & Patino, 1996).

The spare and precise language of word problems leaves many language-minority students yearning for more background information to help them construct a context for the problem. Language-minority students are often literal readers and may search for a paraphrase or a repetition that just isn't present in the problem statement. Students need to learn when background details are necessary to solve a problem, and when they aren't (Dale & Cuevas, 1992). However, teachers should also be aware that teaching students to rely on key words or rules to solve math problems can "limit students' ability to solve problems that are presented in ways that use the key words differently or confound the rules" (Schwartz, 1991). When appropriate, word problems can be simplified by shortening sentences, maintaining active voice, and using the present tense. Sentences with complex grammar, such as phrases and subordinate clauses within clauses, can be broken up and simplified (Secada & De La Cruz, 1996). Eventually, students must be exposed to the richer and more complex language demands of increasingly difficult word problems.

Writing activities in mathematics give students practice in communicating their knowledge and helps them to clarify concepts. These written materials provide opportunities for teachers to informally assess students' conceptual and language development (Kang & Pham, 1995). Students gain valuable language practice and depth of understanding from writing exercises that require them to explain a problem and their strategies to solve it. Teachers can incorporate journal and letter writing into the curriculum. In their journals, students can summarize, organize, and relate ideas, clarify concepts, and review topics. They can describe their strategies, accomplishments, frustrations, and other emotional responses (Anstrom, 1997).

Math projects in which students gather public opinions on topics and then graph the responses involve students in selecting topics, writing questionnaires, interviewing people, and computing and reporting results. Students can write reports on these projects, addressing other students, parents, or community members. They can do more explorative writing by keeping math logs and writing proposals, reports, resumes, portfolios, and their own word problems. Copying information from the board, translating mathematical formulas into complete sentences, summarizing and interpreting a problem and the strategy they used to solve it, are all tasks that help to develop mathematical language skills (Kang & Pham, 1995; Reyhner, 1994).

Vocabulary Development

Learning the vocabulary of English can become particularly complicated for language-minority students when words are not translatable between English and their home language. Comparable terms and parallel ways of considering ideas may not exist across languages, write Lee and Fradd (1998), or, if they do exist, they may not be used with the same frequency or manner.

"As a result, students may circumlocute to convey meanings and produce large quantities of talk or utterances," they write. "By saying too much or too little, students may give the impression that they do not understand when they simply lack specific language or communication patterns to express precise meanings ...."

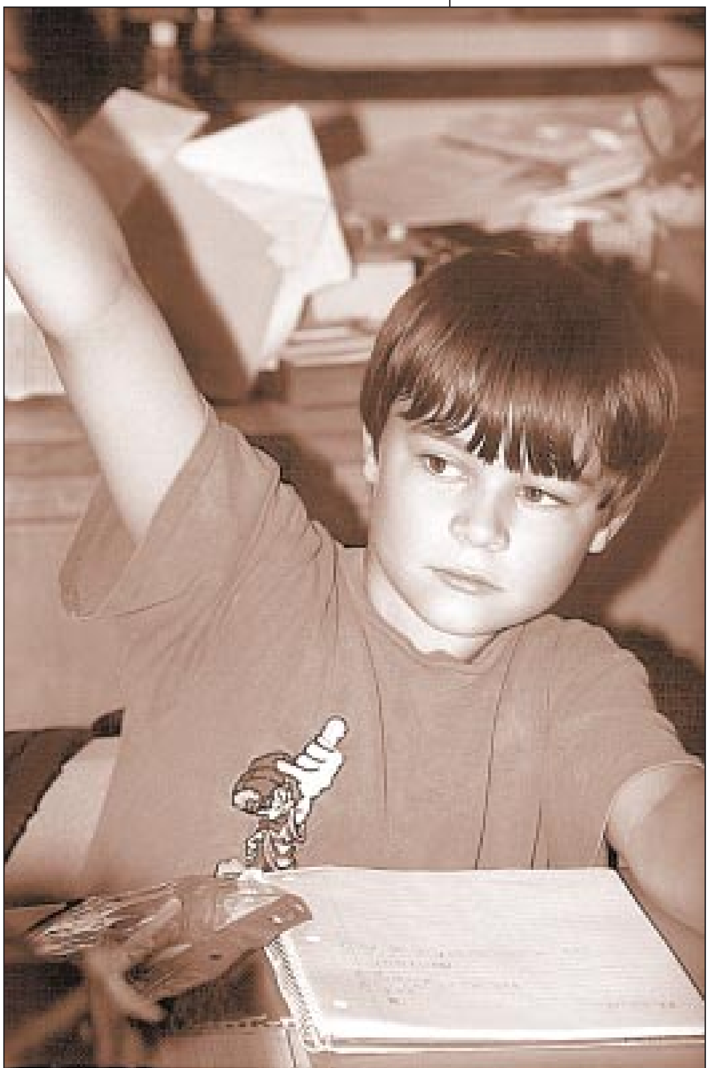
Students learn new terminology and word meanings best when they encounter them during purposeful activities and investigations. Therefore, teachers will want to teach vocabulary as part of their core instruction, not as a separate activity. Teachers can support vocabulary learning by supplementing discussions and activities with real objects, pictures, and visual supports (Laplante, 1997). The meaning of abstract information can be made more explicit in charts and graphs (Fathman, et al., 1992). When new words are introduced, teachers should clearly convey the meaning of the words, then check students' understanding. When students have learned new terminology successfully, they should be able to use newly acquired terms in different contexts (Laplante, 1997).

"Appropriate use of key science terms is an indicator of the precision and sophistication of understanding," write Lee and Fradd (1998).

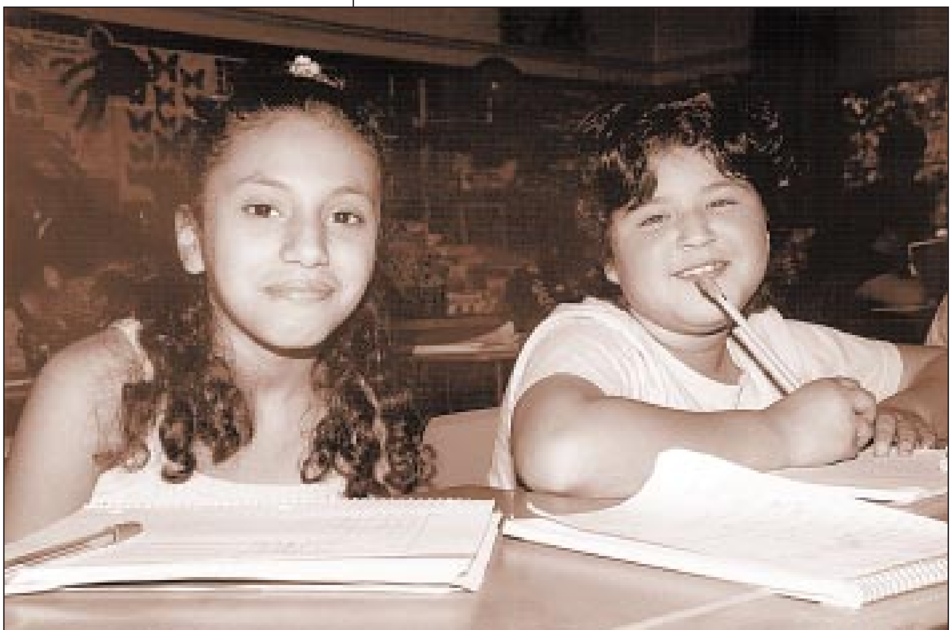
Fathman and colleagues (1992) recommend limiting the introduction of new vocabulary to fewer than 12 words per lesson. Students' knowledge of terminology in their home language or, in some cases, the Latin origins of words, can help them to decipher meaning. Some students may understand the meaning of a word better after they have done an activity involving the thing or idea that is being named. Finally, teachers can help students to build their science and mathematics vocabulary by reintroducing key words in different contexts and guiding students to use these words during investigations and problem solving.

Classroom Discourse

Teachers can help make the language of mathematics and science more comprehensible to their language-minority students by modifying their own speech. By using an active voice, limiting the number of new terms, paraphrasing or repeating difficult concepts, and using visual supports, teachers can facilitate students' language comprehension. Teachers may find it helpful to speak slowly, enunciate clearly, use a controlled vocabulary (i.e., fewer pronouns) and simple language structures, and avoid idiomatic expressions. Words that have double meanings or synonyms should be defined and other descriptive clues provided. It can also help to use longer pauses and nonverbal language such as facial expressions, gestures, and dramatization. Manipulatives and other concrete materials such as props, graphs, visuals, transparencies, bulletin boards, maps, and other realia (real artifacts), can be very helpful to language learners. Teachers will want to check frequently for students' understanding by eliciting requests for clarification, posing questions of varying levels of complexity, and facilitating teacher-to-student and student-to-student interaction (Anstrom & Lynch, 1998; Buxton, 1998; Kang & Pham, 1995). Checking for students' comprehension enables teachers to know when students are ready for more complex language.



Language-minority students are often reticent to join classroom discussions. It may be that they're simply unsure of their English-language skills or feel alienated from the classroom culture. Or it may be that the conventions of their home cultures regarding verbal interaction, particularly between children and adults, may differ from those expected in the classroom. To foster rich discussions in which all students contribute, teachers will want to ensure that there are "entrances" into the conversation (Dalton & Sison, 1995). One way to achieve this is to facilitate student-to-student discussions about important concepts in which students feel free to use their social and academic language skills. This might mean that students will recall personal anecdotes to illustrate their point or to provide evidence to support their theory. Students might joke, talk simultaneously, pepper their speech with their home language, or offer analogies from their out-of-school experiences (Dalton & Sison, 1995). During this, the teacher can often recede into the background, intervening only to keep the discussion progressing constructively or to ensure that all students contribute to the discussion. Sometimes, the teacher might use students' own terminology if it seems to capture meaning in a way that will be understood by other students. In this way, the precise use of specialized language is "leavened with the use of children's own language" (Secada & De La Cruz, 1996).



The key to orchestrating a student-to-student discussion is to plan ahead. Determine in advance what the curricular objective is for the discussion. Is it to elicit students' prior knowledge or to monitor their current level of understanding about a concept or activity? Is it to help them move from concrete knowledge to more abstract thinking? What statements might students make that will show their understanding? What "unpredictable utterances" might students make and how can the teacher be prepared to respond effectively to them? How will students interact—by raising their hands, taking turns, or talking simultaneously (Dalton & Sison, 1995)?

Teachers will want to select discussion topics that will encourage students to talk about their personal experience and background knowledge. Teachers can ask open-ended questions that will encourage them to talk about themselves in the context of the topic. Teachers can prepare questions and prompts to find out what students are thinking about the meaning of the activity. And they can ask students to restate, summarize, and justify their remarks based on their experience in the activity. Anticipating obstacles that might interfere with students' understanding, teachers can prepare concrete materials and visuals to introduce into the dialogue when needed. When the discussion concludes, teachers will want to reflect on how well students now understand the topic. Can they use the ideas and information on their own? Or is another activity or conversation needed to further develop their knowledge of the topic (Dalton & Sison, 1995)?

Affective Influences

Teachers can help language-minority students feel welcome in the inclusive classroom by encouraging them to express their ideas, thoughts, and experiences and by showing respect for students' current language skills. Though at times it can be helpful to repeat or paraphrase students' remarks in class (such as when prompting a student to elaborate, checking for understanding, validating a student's contribution, or modeling proper English), teachers will want to be careful not to embarrass the student or to change the meaning of the student's remark. This is likely to discourage students from trying their English-language skills and engaging in the discourse of the classroom. Often the most effective and graceful approach is one that focuses on *what* the student is saying, not on how she says it, with corrections being ancillary to content instruction. Students should be encouraged to experiment with their new English-language skills without fear of embarrassment (Anstrom & Lynch, 1998; Fathman, et al., 1992; Kessler, et al., 1992; Lockwood, 1998).

Assessment

Decoding the language of a paper-and-pencil test can hinder language-minority students from demonstrating what they know. Teachers will want to use a variety of assessment methods to provide a more complete picture of students' progress and areas of need. They will want to focus on ways students can show what they do know and use this information to guide instruction (Buchanan & Helman, 1993).

Standards-based instruction emphasizes tasks that are rich in language, such as open-ended tasks, journal writing, reflection, and explanation. Teachers need to monitor and assess their students' language development as well as their understanding of content knowledge. **Formative assessments** are administered during a lesson to help teachers to determine their students' current level of language proficiency and conceptual understanding. Formative assessments are not used for grading purposes, but provide both teacher and student with valuable feedback about the student's progress. These assessments might include student demonstrations, written projects, and interviews between teacher and student.

Students can create **concept** and **semantic webs,** demonstrating their understanding of relationships between key ideas or components of a text. During discussions, teachers can use **checklists** to check students' content knowledge as well as their listening and vocabulary skills. They can observe how well students respond to questions and how well they can explain their reasoning, keeping anecdotal records of these observations. Rating scales and rubrics, portfolios of students' homework, logs, and writing assignments can also help teachers to track students' progress and to detect misconceptions (Kang & Pham, 1995).

Performance assessments that focus on students' processes for completing a task or solving a problem, rather than just the results of their work, also can be valuable assessment tools. However, performance assessments may need to be adapted for students who are still learning English and those who have not grown up in households where language forms and uses parallel those of the classroom. To make appropriate adaptations, teachers will first need to analyze the language demands of each performance assessment (Koelsch, Estrin, & Farr, 1995). The authors of the *Guide to Analyzing Cultural & Linguistic Assumptions of Performance Tasks* (Koelsch, et al., 1995), a publication of WestEd in San Francisco (formerly called Far West Laboratory for Educational Research and Development), write: "Language is used in oral and written instructions that are at times lengthy and complex. Assessments from any subject area often require reading of extended passages .... Even mathematics assessments now commonly demand that students write about how and why they solved a problem as they did—something that calls for both cognitive insights (metacognition) and the ability to express these insights clearly in language ...."

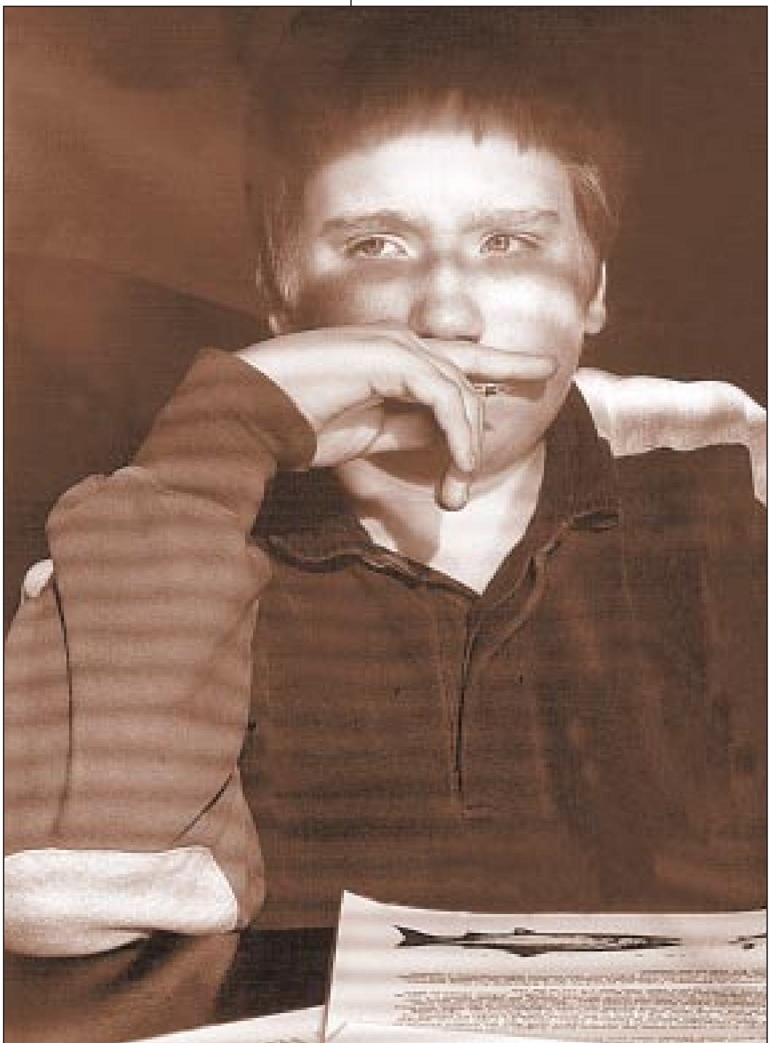
Despite the language demands of performance assessments, they can offer significant opportunities for students to display their learning in meaningful ways. Teachers can allow students to choose the timing and pacing of the assessments or provide input into the topic or choose how they will represent their knowledge (i.e., orally, in writing, using multimedia, etc.). Teachers can also adapt or create new tasks to make assessment more meaningful and authentic for language-minority students. To be authentic, an assessment should be open-ended, accommodate different learning styles, and require students to represent their knowledge in various ways. When creating assessments, teachers should consider students' prior experiences with the concepts, knowledge, skills, and applications called for (Koelsch, et al., 1995).

Teachers will want to recognize when students' level of English proficiency affects their responses on open-ended tasks. The book *Guide to Scoring LEP Student Responses to Open-Ended Mathematics Items* (Kopriva & Saez, 1997), published by the Council of Chief State School Officers, identifies common responses language-minority students make to open-ended tasks. For example, a student might switch codes in a sentence containing elements from both the student's first and new languages, such as using the Spanish word *es* for the English word *is*. The student might also follow the rules of syntax or word order used in his home language; for example, transposing the English phrase *the blue house* to *the house*

blue. Students may apply sounds from their home language to English words, such as writing *rait* for the English word *right.* They may use spelling conventions from their home language to write English words. They might omit tense markers, articles, plurals, prepositions, or other words because they lack understanding of English conventions or because there is no equivalent convention in the students' home language.

The authors also state that language-minority students' responses might follow a circular style. These responses are often fuller and richer than traditional responses, and can be more wordy and include secondary information which the student does not directly connect to the subject at hand. They may use long descriptive sentences. Students may not begin their response with a topic sentence or main point, but lead up to this with lengthy paragraphs. Other students might prefer a brief response style where every sentence in a paragraph is a topic sentence. Students might substitute common words for precise mathematical terms and concepts, such as *fattest* for *greatest,* and *smallest* for *fewest.* They can be confused by words that can have multiple meanings. For example, in mathematics, the word *left* can indicate location or what's remaining, and the word *whole* can mean whole number or all of the parts (Kopriva & Saez, 1997).

Finally, the authors note that students often interpret test items based on their cultural values, sometimes leading to their misunderstanding. For example, students whose culture does not emphasize winning may respond to a test item directing them to create a race course that is most fair for all contestants by designing a course in which slower runners run shorter distances—thereby giving slower and faster runners the same chance at winning the race (Kopriva & Saez, 1997).



Reading and writing assessment activities are essential for gauging and developing students' language proficiency (Bernhardt, Destino, Kamil, & Rodriguez-Munoz, 1995). Ideally, students should have opportunities to demonstrate their conceptual understanding in writing using their home language as well as English. When available, assessments using the student's home language can help teachers to determine whether concepts presented in English have been successfully mastered (Buxton, 1998).

Finally, teachers should be on the lookout for the many cues, often nonverbal, that students give which reflect their level of understanding, such as "Aha!" expressions or looks of confusion. Secada and De La Cruz (1996) note some of the many ways that teachers can detect students' conceptual and language comprehension:

- Ask students if they understand one another's explanations
- Listen to see if students are restating in their own words what has been said by others
- Notice if students relate an idea or statement to a different event
- Ask students to explain or elaborate their reasoning
- Notice when students point out something that is wrong with an idea, showing that they understand that idea
- Ask if anyone has solved a problem in a different way or can give a new way of justifying an idea

- Ask a student to explain, in his home language, his strategies and reasoning to a bilingual student who is proficient in English, then ask that student if the explanation made sense to him
- To draw language-minority students into classroom discussions, teachers can, when appropriate, ask an English-proficient bilingual student to translate another student's remarks

All the World Smiles in the Same Language

Richmond Elementary, Salem, Oregon

By inviting parents into her mathematics classroom, one teacher opens the door to learning for the whole family. With parents by their sides, children venture boldly into the world of math.

THE NEIGHBORHOOD OF RICHMOND ELEMENTARY SCHOOL consists of small wood-frame houses. Sunlight plays among a canopy of maple and oak trees, giving homes and sidewalks a dappled and affable appearance. Like the neighborhood, the school is old and comfortable, kept cheery by fresh paint, wall displays, and caring adults. This is Salem, the capital of Oregon and the population center of the fecund Willamette Valley. Many of Salem's residents, from its earliest settlers to today's newcomers, were drawn to the valley's agricultural economy. People of Hispanic descent have long been part of this community, helping to shape the prosperity and character of the city by, in part, working in its outlying orchards, nurseries, and landscaping enterprises. Today, many of their children attend Richmond Elementary, where nearly all students are from Spanish-speaking families.

This morning at Richmond, the aged hallways and classrooms quicken once again to the irrepressible sounds of children. Nancy Anderson, math resource teacher, is anticipating the arrival of a visiting class of second-graders. She is setting up math stations around the room, distributing materials for a series of activities involving patterns. She surveys the tight arrangement of little tables and chairs, wondering how many parents might show up and whether there will be enough room for the inevitable baby strollers and wandering toddlers. It's fine, we'll manage, she thinks.

The second-graders arrive with restrained eagerness. They slide into chairs and listen to Anderson's directions as closely as seven-year-olds can manage. Joining Anderson are second-grade teacher Stan Lewin and four mothers. The mothers have come, as some do every week, to Anderson's laboratory to take part in the math activities, assisting their children with directions and hands-on tasks, and picking up packets of activities to do as a family at home. Babysitters being rare, parents often bring their younger children with them. While mothers nurse infants, their toddlers join the second-graders in classroom activities, piping up, "Me!", when Anderson asks for volunteers.

Anderson has been very successful in encouraging parents to come to math lab with their children. She sends invitations to parents in English and Spanish, with the dates and times of the laboratories. Then she prompts the children to remind their parents, which they do eagerly. The response from parents has been strong; last year, parents attended the laboratories nearly 400 times.

"I invite them to bring their little ones because the little ones can access the math lessons, too," says Anderson.

The bustle, the noise, the disorder: Anderson takes it in stride. Lifting one of the four-year-olds into her arms, she helps him lead the class in counting from one to five. His face glows. When this child enrolls for school in a year or so, she hopes, he'll remember this moment.

The child in Anderson's arms is Claudia's youngest of four sons. When Claudia was in seventh grade, Anderson was her teacher. She has fond memories of being a pupil in Anderson's class, but later, as a high school student, she dropped out, marrying a young man from Mexico. Now, with four children under the age of seven, Claudia is determined that they will succeed in school. So she comes with her eldest son, second-grader Jorge, and his younger brothers to math lab. As a family, they move from one tiny table to the next as Jorge progresses through each station of activities. Claudia's eyes are everywhere: checking Jorge's progress on a task and tracking his brothers as they dart about the room, delighted to be in on the action.

"It's a real job for parents to come in with three or four kids and try to participate in math lab, but more and more parents are doing that," says Anderson. "It's gotten pretty chaotic at times with parents, strollers, and babies trying to move from table to table—I've carried my share of babies!"

Often, parents are accompanied by other adult family members. At a recent math lab for the parents of the fourth- and fifth-graders, 11 extended families attended, totaling about 55 adults. Undaunted, Anderson quickly moved the lab from the classroom to the cafeteria. It's important to her that parents come to the school and participate in their children's education in any way they can manage, she says. Any crowding is just a healthy sign of parent involvement.

"That's what's going to make the change in the future of these kids," she says. In math lab, Anderson models for the parents how they can support their children's learning by asking probing questions, eliciting meaningful responses from their children, and encouraging creativity while having high expectations. As with students, says Anderson, "you can't tell them, you have to show them."

She's noticed that those children who visited her math labs as toddlers are more ready to learn when they come to Richmond as kindergartners. For many, math lab introduced them to the fun of mathematics, she says, giving these preschoolers a positive school experience even before they're enrolled. Because language can be a formidable obstacle to school success for non-English speakers, any boost that can help language-minority students when they first come to school is important. And when a student overcomes some of the challenges and begins to succeed in school, it is very rewarding for teacher and student alike, says Anderson. At Richmond, she says, "hope is very evident. If I had to choose a place to work, it would still be Richmond. It's a real loving place."

She credits principal Kathy Bebe for infusing the school with a sense of fairness, good spirit, discipline, and high expectations, despite the challenges. From office to custodial staff, from teachers to students, most everyone feels like a valued member of the school, Anderson says. This climate results partly from a formal program Bebe instituted at the school called Love and Logic, which helps children learn personal responsibility. The rest must be attributed to the shared will and wisdom of the adults who are charged with the education of these young people. In a hallway at Richmond is posted a Mexican proverb, "All the world smiles in the same language." Somehow, this captures the spirit of Richmond Elementary better than anything else.

Collaborating with Other Teachers

MOST MATHEMATICS AND SCIENCE TEACHERS IN GENERAL education classrooms are monolingual and don't have expertise in second-language instruction. Yet many teachers have language-minority students in their classes. One of the best ways to deal with this dilemma is to collaborate with a bilingual or English-as-a-second-language (ESL) specialist in the school or district. By collaborating, content and second-language teachers can combine their skills and knowledge to implement more effective curriculum, activities, assessment, and resources for language-minority students—for the general education classrooms as well as for the ESL or bilingual classroom. Furthermore, sharing these tasks can enable each teacher to optimize his or her available time (Kang & Pham, 1995).

> COLLABORATION AMONG TEACHERS CAN PROVIDE AN ENVIRONMENT IN WHICH SECOND-LANGUAGE AND LITERACY DEVELOPMENT CAN EXIST ACROSS THE CURRICULUM AND SCHOOL DAY, LEADING TO INCREASED OPPORTUNITIES FOR ACADEMIC SUCCESS AMONG ESL STUDENTS.
>
> —Kang & Pham (1995)

Second-language teachers can assist content teachers in designing curriculum that is infused with language activities and can extend that curriculum into the ESL classroom where it can be reinforced. Second-language teachers can analyze the content objectives, as well as the language abilities students need to master the content, to determine a basis for language activities in the ESL classroom.

Content teachers can help design and develop mathematics and science-based materials to be used in ESL classes. They can also help second-language teachers to incorporate problem-solving activities into the ESL class. This will support students' learning of the specialized language and ways of thinking in mathematics and science. It will provide a purposeful context for practicing more complex language skills as well as higher-order thinking skills (Kang & Pham, 1995; Minicucci, 1996).

Finally, teachers will want to seek ways to collaborate with other content teachers. Creating cross-disciplinary units can foster a learning environment that is rich in context, with ample opportunities for students to make connections to real life and their personal experiences. It also creates more time for language-minority students to learn and use the specialized language associated with the topic of the unit (Minicucci, 1996). Teachers who do not speak their students' home language might team teach with another content teacher who does. Such collaboration can be especially useful at the secondary level, where disciplines are often compartmentalized into separate departments (Radford, et al., 1997).

Content and language teachers can collaborate by (Buxton, 1998):

- Observing each other's classrooms
- Identifying specific linguistic and academic difficulties and demands that the content presents
- Selecting themes for interdisciplinary units and lessons
- Identifying objectives of the unit to be taught
- Identifying key terms and words to introduce in advance
- Adapting written materials to appropriate language levels
- Extending content and objectives into the ESL classroom
- Creating audio tapes, study guides, and outlines of lessons
- Previewing lessons in students' home languages when appropriate

Involving the Family

A SOMETIMES OVERLOOKED SOURCE OF KNOWLEDGE AND support for the teachers of language-minority students are the children's family members. Naturally, they know the child best. They usually share the child's background and home language. They know where the child's talents lie; they know her weaknesses; they know in which situations or environments she learns best. From them, she has gained many of her first beliefs, knowledge, and understanding of the world, as well as how to interact in it. Her world view may differ from Western views expressed in the mathematics and science classroom. The continued presence of family members in her educational life can help her to bridge the differences that often exist between home and school.

> A FAMILY MEMBER WOULD SAY SOMETHING TO ME AND I WOULD FEEL MYSELF SPECIALLY RECOGNIZED. MY PARENTS WOULD SAY SOMETHING TO ME AND I WOULD FEEL EMBRACED BY THE SOUNDS OF THEIR WORDS.
>
> —Richard Rodriguez (1982)

Parents can be an inestimable help to the teacher. They can tell teachers about the child's previous school experiences, provide information about the child's learning styles and needs, and share with the teacher their hopes and goals for their child. They can reinforce classroom learning at home. They can volunteer at the school, helping with activities, events, and translation needs. They can even help a teacher design a curriculum relevant to language-minority students by offering ideas, being guest speakers in the classroom, and helping teachers find resources and other guest speakers from the child's community.

It can take a long time to nurture and forge a strong home-school link. It may take many contacts with family members and other people in the students' home communities to bridge differences in language, cultural customs, and educational experiences. Family members may be very hesitant to get involved. They may have negative memories of their school experiences or feel inadequate. Their cultural background may lead them to respect authority figures to the degree that they feel they shouldn't interfere with official practices. Also, many parents are working very hard—perhaps at two or three jobs—and simply don't have the time or energy to take an active role in their child's education. Lack of transportation and child care can limit parents' ability to come into the schools (Gonzalez, Brusca-Vega, & Yawkey, 1997).

While the realities of daily life can make it difficult, it is possible to forge a link between homes and schools. The key is to start slow, says Virginia Gonzalez (1997), "taking small steps, one at a time, toward school involvement." With a sincere effort and desire to create ties with children's family members, the smallest beginnings can lead to productive relationships, with the rewards being reaped by students.

When teachers and parents first meet, perhaps on the first day of school, teachers can create a welcoming impression by inviting them to stay in the classroom for a few minutes. Each subsequent contact with parents should reinforce this welcome. Notes, calls, and visits—both home and school visits—can be done periodically to let parents know when their child has done something positive, not just when the teacher is concerned about achievement or behavior. By writing notes or calling periodically to inform parents of important information or to ask for their thoughts about an idea, teachers can make it evident to parents that their input is valued and that they are welcome at the school. Parents should be kept informed about what is expected of their child in mathematics and science; especially at the secondary level, parents should be told which courses are required for graduation and college application. Home visits are often a very good way to meet with parents. The informal environment can help everyone to interact more readily and genuinely (Gonzalez, et al., 1997).

What occurs in the classroom also lets parents know whether their child's language and culture are welcome. For example, extending classroom conversations into the home is one way to forge a link between home and school. As a regular practice, students can be encouraged each day to take home one piece of information to share with their family, or one question that they can ask their parents or other adult family members. Teachers might design lessons in which students talk to their parents and family members about their own childhood, home country, work experiences, and ways of doing things. Students can then relate this information to the teacher or whole class, in either spoken or written English. This supports students' home language and culture, as well as academic and English-language learning (Ada, 1995). For example, a parent in a Yup'ik community in

Alaska might talk about traditional fishing skills, perhaps touching on the life cycle of the salmon or the craft of fashioning waterproof boots out of fish skins. A farm worker in Washington might talk about agriculture and work in the fields, areas that involve measuring skills and operating technological tools. They might even lead to parents coming into the classroom to share their knowledge with the whole class (Gonzalez, et al., 1997). Students might also write a periodical newsletter in their home language for parents, including photographs of themselves and their school work. All of these activities can help to foster communication in the home and can promote students' language and content development (Ada, 1995).

Students Vie to Attend Science Magnet School

Central Middle School of Science, Anchorage, Alaska

Turning a faltering middle school into a vibrant place of learning gave students and teachers at one urban school the rich taste of success. For those pupils not yet fluent in English, academic success can mean the difference between living at the margins of American society and taking one's rightful place in it.

It was her first year of teaching. Fresh out of college, science teacher Jan Davis was assigned to an intermediate school in Riverside, California with a largely Hispanic student population. Jose, one of the youngsters in her class, was just learning English. Each morning, he'd stand with his classmates to say the Pledge of Allegiance, placing his left hand over his heart. "No," Davis would tease him kindly, "your other left hand." One day, in his ESL class, Jose was called on to name his two hands. He promptly replied: "This is my left hand, and this is my other left hand."

Davis recalls this story with a laugh, poking fun at her clumsy attempt to teach a young language-minority student. But the lesson had a lasting impact.

"It taught me that I couldn't take for granted that they knew more than they really did, even if he could say 'yes' and 'no' and seemed to understand everything being said in the classroom and on the playground," she recalls. "It taught me to evaluate and not assume what they know."

Davis, 31, grew up in Anchorage. In fact, she attended Central as a junior high student. After meeting her future husband during a Christmas visit home to Anchorage, Davis moved back to Alaska. While Central is not nearly as diverse as the school in Riverside, 40 percent of its students are from an ethnic minority group and about 9 percent of them are language-minority students. Davis is now quite expert at teaching students for whom English is not their first language. They come to her science classes in various stages of English proficiency, and she engages them in scientific inquiry through instructional techniques that support their language development as well as their understanding of science.

When Davis returned to her alma mater to teach, she found it a changed place. In fact, the school had undergone a couple of overhauls. When principal Keith Taton came to the school in 1990, the school was known as Central ABC Alternative School, the ABC meaning "Anchorage Basic Curriculum." After a few years of struggling with high turnover and low morale among students and faculty, Taton decided that the school needed restructuring. He brought together teachers, university educators, and members of the business community to brainstorm ideas. The consensus was that students would be best served by emphasizing mathematics, science, and technology across all disciplines. So, in 1993, Taton transformed the school by integrating science into all areas of the core and elective curriculum, and creating flexible block scheduling to accommodate extended projects. Since then, students' mathematics achievement scores have gone up, and students frequently win national science awards. These successes have brought Taton recognition for his vision; including being a recent finalist for National Principal of the Year awarded by the National Association of Secondary School Principals.

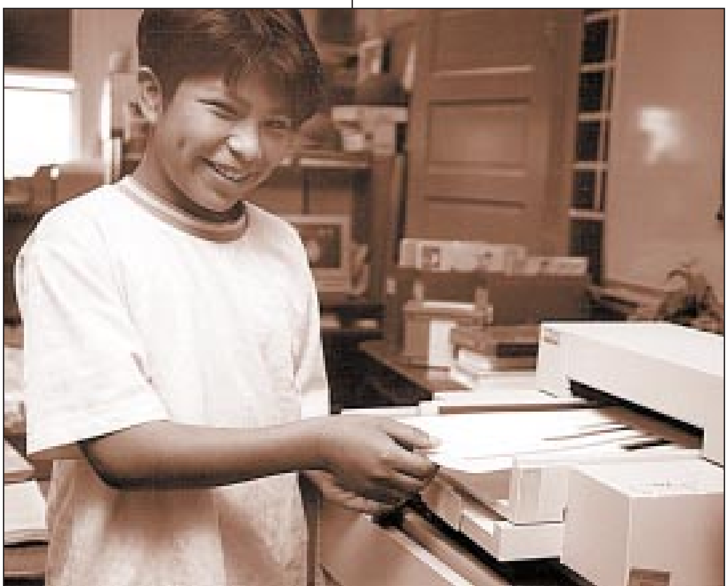
One of the most rewarding changes, says Taton, is that enrollment in the school is now hotly contested—every year, there is a waiting list of prospective pupils. Now, students are more eager to get in than to get out. As a magnet school, 40 percent of the students at Central apply to attend through a lottery. Taton takes some pride in the fact that 15 percent of the students who are attending Central through the lottery are minority students.

The restructuring had a great effect on school morale. "It changed the whole culture of the school," says Taton. He says it not only energized teachers and students, but also revitalized community support. Taton credits community encouragement for the school's ability to obtain nearly $4 million in funds to renovate the aging building. The jewels in the crown will be wet labs with computer stations between each two science classrooms. While wet labs will enhance Davis' science classroom by no small measure, her biggest satisfaction remains her relationship with students.

"Teaching ESL students is very gratifying because they're little sponges, and because you know how hard it is for them," she says. "But once they feel comfortable, they just soar."

Conclusion

IN TODAY'S INCREASINGLY DIVERSE CLASSROOMS, STUDENTS' cultural backgrounds, home languages, life experiences, and ways of learning can vary a great deal. Teachers will want to use instructional strategies that respect and build on these differences while helping all students learn important concepts and skills in mathematics and science.



This publication highlights effective instructional approaches that link second-language acquisition strategies with other standards-based practices. These strategies can help the general education teacher meet the learning needs of language-minority students. The following pages contain additional resources that may be helpful to teachers in inclusive classrooms.

Resources and Bibliography

MANY OF THESE RESOURCES ARE AVAILABLE THROUGH NWREL's Mathematics and Science Education Center lending collection. Contact the resource specialist at (503) 275-9499 or math_and_science@nwrel.org to learn how to access these resources. The Web site addresses (URLs) listed here were current at the time of printing, but may be subject to change.

Resources for further reading

Barba, R.H. (1995). *Science in the multicultural classroom: A guide to teaching and learning.* Boston, MA: Allyn and Bacon.

Cary, S. (1997). *Second language learners: Strategies for teaching and learning.* York, ME: Stenhouse & Los Angeles, CA: Galef Institute.

Eastern Stream Center on Resources and Training, Appalachia Educational Laboratory, & Center for Applied Linguistics. (1998). *Help! They don't speak English starter kit for primary teachers: A resource guide for educators of limited English proficient migrant students, grades Pre-K-6* (3rd ed.). Oneonta, NY: Eastern Stream Center on Resources and Training, Charleston, WV: Appalachia Educational Laboratory, & Washington, DC: Center for Applied Linguistics.

Faltis, C.J., & Wolfe, P.M. (Eds.). (1999). *So much to say: Adolescents, bilingualism, and ESL in the secondary school.* New York, NY: Teachers College Press.

Garrison, L. (1997). Making the NCTM's standards work for emergent English speakers. *Teaching Children Mathematics, 4*(3), 132-138.

Gibbons, P. (1991). *Learning to learn in a second language.* Portsmouth, NH: Heinemann.

Hargett, G.R. (1998). *Assessment in ESL & bilingual education: A hot topics paper.* Portland, OR: Northwest Regional Educational Laboratory.

Harris, J.W. (1995). Sheltered instruction: Bridging the language gap in the science classroom. *The Science Teacher, 62*(2), 24-27.

Kessler, C., & Quinn, M.E. (1981, January). *Consequences of bilingualism in a science inquiry program.* Paper presented at the annual meeting of the Southwest Educational Research Association, Dallas, TX. (ERIC Document Reproduction Service No. ED 203 721)

Lavadenz, M. (1996). Authentic assessment: Toward equitable assessment of language minority students. *New Schools, New Communities, 12*(2), 31-35.

Martinez, R.D. (1999). *Assessment: A development guidebook for teachers of English-language learners* (2nd ed., with trainer's manual and workshop materials). Portland, OR: Northwest Regional Educational Laboratory.

Merino, B.J., & Hammond, L. (1998). Family gardens and solar ovens: Making science education accessible to culturally and linguistically diverse students. *Multicultural Education, 5*(3), 34-37.

Navarrete, C., & Gustke, C. (1996). *A guide to performance assessment for linguistically diverse students.* Albuquerque, NM: New Mexico Highlands University, EAC West. Retrieved June 30, 1999 from the World Wide Web: www.ncbe.gwu.edu/miscpubs/eacwest/perform.html

Northwest Regional Educational Laboratory. (1998). *Improving education for immigrant students: A guide for K-12 educators in the Northwest and Alaska.* Portland, OR: Author.

Reyhner, J., & Davison, D.M. (1992, August). *Improving mathematics and science instruction for LEP middle and high school students through language activities.* Paper presented at the Third National Research Symposium on Limited English Proficient Student Issues: Focus on Middle and High School Issues, Washington, DC. Retrieved June 30, 1999 from the World Wide Web: www.ncbe.gwu.edu/ncbepubs/symposia/third/reyhner.htm

Richard-Amato, P.A., & Snow, M.A. (Eds.). (1992). *The multicultural classroom: Readings for content-area teachers.* White Plains, NY: Longman.

Rosebery, A.S., Warren, B., & Conant, F.R. (1992). *Appropriating scientific discourse: Findings from language minority classrooms.* Santa Cruz, CA: National Center for Research on Cultural Diversity and Second Language Learning. (ERIC Document Reproduction Service No. ED 352 263)

Rosebery, A.S., Warren, B., & Sylvan, L. (1995). Scientific sense-making in bilingual education. *Hands On!, 18*(1). Retrieved June 30, 1999 from the World Wide Web: www.terc.edu/handson/spring_95/sensemaking.html

Secada, W., & Carey, D.A. (1990). *Teaching mathematics with understanding to limited English proficient students.* New York, NY: ERIC Clearinghouse on Urban Education.

Secada, W.G. (1996). Urban students acquiring English and learning mathematics in the context of reform. *Urban Education, 30*(4), 422-448.

Tannenbaum, J. (1996). *Practical ideas on alternative assessment for ESL students.* Washington, DC: ERIC Clearinghouse on Languages and Linguistics (ERIC Digest No. EDD-FL-96-07). Retrieved June 30, 1999 from the World Wide Web: www.ed.gov/databases/ERIC_Digests/ed395500.html (ERIC Document Reproduction Service No. ED 395 500)

Warren, B., & Rosebery, A.S. (1995). Equity in the future tense: Redefining relationships among teachers, students, and science in linguistic minority classrooms. In W.G. Secada, E. Fennema, & L.B. Adajian (Eds.), *New directions for equity in mathematics education* (pp. 298-328). New York, NY: Cambridge University Press.

Organizations

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Phone: 1-800-601-4868
Web: eric-web.tc.columbia.edu/pathways/immigrant_issues/

The ERIC Clearinghouse's immigrant issues pathway on the Urban Education Web is designed for those who are either involved in educating immigrant students or interested in learning more about the world of immigrant students and how we can better meet their needs. The pathway offers collections of Internet resources on various topics researched and compiled by Urban Education Web.

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The National Association for Bilingual Education (NABE) addresses the educational needs of language-minority students. Through research, professional development, public education, and legislative advocacy, NABE supports the implementation of educational policies and practices which ensure equality of educational opportunity for the increasingly diverse students of America.

National Clearinghouse for Bilingual Education
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NCBE is a program of the U.S. Department of Education's Office of Bilingual Education and Minority Languages Affairs (OBEMLA). It collects, analyzes, and disseminates information relating to the effective education of linguistically and culturally diverse learners. NCBE serves as a broker for exemplary practices and research as they relate to the education of language-minority students. It is a source of information for classroom teachers and individuals working in foreign-language programs, English-as-a-second-language programs, Head Start, Title I, Migrant Education, and Adult Education programs.

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The center provides Northwest K-12 educators with resources and services to support challenging and effective curriculum, instruction, and assessment. Teacher guides and support materials, assessment ideas and samples, research syntheses, and other items are accessible by a searchable database. Northwest educators may borrow materials via online requests. The It's Just Good Teaching series includes publications and videos that promote effective instructional strategies. The publications can be ordered or downloaded from the center's Web site.

Bibliography

Ada, A.F. (1995). Fostering the home-school connection. In J. Frederickson (Ed.), *Reclaiming our voices: Bilingual education, critical pedagogy & praxis* (pp. 163-178). Ontario, CA: California Association for Bilingual Education.

American Association for the Advancement of Science. (1998). *Blueprints for reform: Project 2061.* New York, NY: Author.

Anstrom, K. (1997). *Academic achievement for secondary language minority students: Standards, measures and promising practices.* Washington, DC: National Clearinghouse for Bilingual Education.

Anstrom, K., & Lynch, S. (1998). *Preparing secondary education teachers to work with English language learners: Science.* Washington, DC: National Clearinghouse for Bilingual Education. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/ncbepubs/resource/ells/science.htm

Ballenger, C. (1996). *Science talk in a bilingual classroom* (Working Paper No. 1-96). Cambridge, MA: TERC Communications.

Bernhardt, E., Destino, T., Kamil, M., & Rodriguez-Munoz, M. (1995). Assessing science knowledge in an English/Spanish bilingual elementary school. *Cognosos, 4*(1), 4-8.

Buchanan, K., & Helman, M. (1993). *Reforming mathematics instruction for ESL literacy students* (NCBE Program Information Guide Series No. 15). Washington, DC: National Clearinghouse for Bilingual Education. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu. edu/ncbepubs/pigs/pig15.htm (ERIC Document Reproduction Service No. ED 363 136)

Buxton, C.A. (1998). Improving the science education of English language learners: Capitalizing on educational reform. *Journal of Women and Minorities in Science and Engineering, 4*(4), 341-369.

Crawford, J. (1995). *Bilingual education: History, politics, theory and practice* (3rd ed.). Los Angeles, CA: Bilingual Educational Services, Inc.

Cummins, J. (1992). Bilingual education and English immersion: The Ramirez report in theoretical perspective. *Bilingual Research Journal: The Journal of the National Association for Bilingual Education, 16*(1-2), 91-104.

Dale, T.C., & Cuevas, G.J. (1992). Integrating mathematics and language learning. In P.A. Richard-Amato & M.A. Snow (Eds.), *The multicultural classroom: Readings for content-area teachers.* White Plains, NY: Longman.

Dalton, S., & Sison, J. (1995). *Enacting instructional conversation with Spanish-speaking students in middle school mathematics.* Santa Cruz, CA: National Center for Research on Cultural Diversity and Second Language Learning. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/miscpubs/ncrcdsll/rr12/index.htm (ERIC Document Reproduction Service No. ED 382 030)

Delpit, L. (1995). *Other people's children: Cultural conflict in the classroom.* New York, NY: W.W. Norton.

Fathman, A.K., Quinn, M.E., & Kessler, C. (1992). *Teaching science to English learners, grades 4-8* (NCBE Program Information Guide Series No. 11). Washington, DC: National Clearinghouse for Bilingual Education. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/ncbepubs/pigs/pig11.htm

Fradd, S.H., & Lee, O. (1999). Teachers' roles in promoting science inquiry with students from diverse language backgrounds. *Educational Researcher, 28*(6), 14-20, 42.

Gonzalez, V., Brusca-Vega, R., & Yawkey, T. (1997). *Assessment and instruction of culturally and linguistically diverse students with or at-risk of learning problems: From research to practice.* Needham Heights, MA: Allyn & Bacon.

Kang, H., & Pham, K.T. (1995, March). *From 1 to Z: Integrating math and language learning.* Paper presented at the 29th annual meeting of the Teachers of English to Speakers of Other Languages, Long Beach, CA. (ERIC Document Reproduction Service No. ED 381 031)

Kaplan, R.G., & Patino, R.A. (1996, October). *The effects of a communicative approach on the mathematical problem solving proficiency of language minority students.* Paper presented at the annual meeting of the Northeastern Educational Research Association, Ellenville, NY. (ERIC Document Reproduction Service No. ED 404 166)

Kessler, C., Quinn, M.E., & Fathman, A.K. (1992). Science and cooperative learning for LEP students. In C. Kessler (Ed.). *Cooperative language learning: A teacher's resource book* (pp. 65-83). Englewood Cliffs, NJ: Prentice Hall Regents.

Koelsch, N., Estrin, E.T., & Farr, B. (1995). *Guide to analyzing cultural & linguistic assumptions of performance tasks.* San Francisco, CA: Far West Laboratory.

Kopriva, R., & Saez, S. (1997). *Guide to scoring LEP student responses to open-ended mathematics items.* Washington, DC: Council of Chief State School Officers.

Laplante, B. (1997). Teaching science to language minority students in elementary classrooms. *New York State Association for Bilingual Education Journal, 12,* 62-83. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/miscpubs/nysabe/vol12/nysabe124.pdf

Latham, A.S. (1998). The advantages of bilingualism. *Educational Leadership, 56*(3), 79-80.

Lee, O., & Fradd, S.H. (1996). Literacy skills in science learning among linguistically diverse students. *Science Education, 80*(6), 651-671.

Lee, O., & Fradd, S.H. (1998). Science for all, including students from non-English-language backgrounds. *Educational Researcher, 27*(4), 12-21.

Lee, O., Fradd, S.H., & Sutman, F.X. (1995). Science knowledge and cognitive strategy use among culturally and linguistically diverse students. *Journal of Research in Science Teaching, 32*(8), 797-816.

Lockwood, A.T. (1998). Ann S. Rosebery & Beth Warren: Professional development & scientific discourse. *Principled Practice in Mathematics and Science, 2*(2), pp. 7-10.

Minicucci, C. (1996). *Learning science and English: How school reform advances scientific learning for limited English proficient middle school students* (Educational Practice Report No. 17). Santa Cruz, CA: National Center for Research on Cultural Diversity and Second Language Learning. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/miscpubs/ncrcdsll/epr17.htm

Radford, L., Netten, J., & Duquette, G. (1997). Developing target second language skills through problem-solving activities in mathematics. *New York State Association for Bilingual Education Journal, 12,* 84-97. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/miscpubs/nysabe/vol12/nysabe125.pdf

Reyhner, J. (1994). *American Indian/Alaska Native education* (Fastback No. 367). Bloomington, IN: Phi Delta Kappa Educational Foundation.

Rodriquez, R. (1982). *Hunger of memory: The education of Richard Rodriquez: An autobiography.* New York, NY: Bantam Books.

Rupp, J.H. (1992). Discovery science and language development. In P.A. Richard-Amata & M.A. Snow (Eds.). *The multicultural classroom: Readings for content-area teachers.* White Plains, NY: Longman.

Schwartz, W. (1991). *Teaching limited English proficient students to understand and use mathematics* (ERIC/CUE Digest No. 70). New York, NY: ERIC Clearinghouse on Urban Education. (ERIC Document Reproduction Service No. ED 334 310)

Secada, W.G., & De La Cruz, Y. (1996). Teaching mathematics for understanding to bilingual students. In J.L. Flores (Ed.), *Children of la frontera: Binational efforts to serve Mexican migrant and immigrant students* (pp. 3-25). Charleston, WV: ERIC Clearinghouse on Rural Education and Small Schools. (ERIC Document Reproduction Service No. ED 393 646)

Spanos, G. (1992, August). *ESL math and science for high school students: Two case studies.* Paper presented at the Third National Research Symposium on Limited English Proficient Student Issues: Focus on Middle and High School Issues, Washington, DC. Retrieved June 1999 from the World Wide Web: www.ncbe.gwu.edu/ncbepubs/symposia/third/spanos.html

Viadero, D. (1999, August 4). Research board urges broad approach to bilingual education. *Education Week, 18*(43), p. 12. Retrieved from the World Wide Web August 4, 1999 at www.edweek.org/ew/vol-18/43nerpp.h18

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