

*Third National Research Symposium on Limited English Proficient Student Issues:
Focus on Middle and High School Issues*

Improving Mathematics and Science Instruction for LEP Middle and High School Students Through Language Activities

**Jon Reyhner and David M. Davison
Eastern Montana College**

Abstract

This paper presents an overview of a series of studies the authors have pursued on how to improve the education of ethnic minority limited English proficient (LEP) students in general and how to improve the education of LEP American Indian students in the areas of mathematics and science in particular. The authors were guided by three research questions: 1) What does past research tell us about what works in American Indian education? 2) What type of mathematics and science curriculum and instruction works best with LEP American Indian students? and 3) Will a focus on writing and other language activities in content area classrooms, such as mathematics and science, improve student performance in those subjects? They found both in the literature and in their own research that when teachers of mathematics and science respect and are knowledgeable of their students' native culture and emphasize writing and other language activities, American Indian students perform better and have a better understanding of mathematics and science.

Introduction

Numerous explanations have been given for the poor academic performance of ethnic minority children in the United States. Most of these explanations focus on the deficiencies of these minority children rather than on the deficiencies of the education programs provided by schools in the United States. During the first half of the twentieth century, explanations pointed to racial causes using evidence from intelligence tests (Gould, 1981). In the 1960s, educators talked about "cultural deprivation" of minority children and even the cultural "vacuum" they came from (Wax, Wax, and Dumont, 1989 [1964]). Throughout these discussions there was an ethnocentric lack of appreciation by educators for the cultural background of ethnic minority children.

In the 1960s and 1970s, explanations were put forward that dealt with students either being unable to learn because of lack of fluency in the language of instruction (see Cummins, 1989) or because of other cultural differences (Spindler, 1987). However, some linguistic minorities experience academic success in immersion situations. Recently, more attention is being given to the role of ethnic and racial prejudice in turning ethnic minority students off to school. Cummins describes four areas where educators need to work to achieve success with "dominated" minorities such as American Indians and Hispanics. These areas include cultural incorporation in the school, community participation, active teaching methods, and advocacy assessment. Too often today, in order to maintain a positive self-identity, these dominated ethnic minority students must take on an anti-school identity and resist the assimilationist demands of the school (Deyhle, 1992; Ogbu, 1987).

The approach of this paper to mathematics and science education for LEP ethnic minority students combines positive culture reinforcement through ethnomathematics and ethnoscience with language assistance. Students' interest and success in school will increase through the implementation of curricular changes that incorporate the home culture of the student, give explicit attention to language development, and focus on student comprehension. Using bilingual and multicultural approaches to education will make it easier for LEP students to buy into schooling.

The authors of this paper take to heart the dictum of Cantieni and Tremblay (1979, p. 248) that "young people learn best from their own and not other people's experiences." It can be added that these classroom experiences of students should not be isolated from one another, but rather should be integrated in a holistic fashion across the curriculum as much as possible so that students can see how mathematics, science, and other school subjects are used in the world beyond the classroom. In other words, the much documented overuse of textbooks in the United States must be decreased, and students need to be given more "hands-on" experiences across the curriculum. This is especially true for LEP students who do not have the academic language competencies to understand the abstract language of textbooks (see, for example, Reyhner, in press).

The authors present in this paper a synthesis of their ongoing studies seeking the causes for the relative lack of school success for children of American Indian ancestry in the United States. They found that educators can do a lot to improve the academic performance of LEP American Indian students through changing how and what they teach. The research questions guiding their work are: (1) What does past research tell us about what works in American Indian education? (2) What type of mathematics and science curriculum and instruction works best with LEP American Indian students? and (3) Will a focus on writing and other language activities in content area classrooms such as mathematics and science improve students' performance in those subjects?

To answer these questions, the authors give, first, an extensive review of research on the education of minority groups in general in the United States and on American Indians in specific. They then describe the methodology, findings, and conclusions of specific studies they have done with American Indian and non-Indian students involving assessing students' language capabilities in both the Crow language and in English and providing language-rich classroom activities. Finally, the authors provide overall conclusions they have drawn from their work and recommendations for improving the instruction of LEP American Indian students.

Review of Research

Oakes (1985) documents how educators have traditionally tracked minority students out of advanced mathematics and science classes, based on intelligence and achievement testing, into low track classes that are less challenging and thus more boring for many minority students. These low expectations are based on deeply ingrained racist ideologies that create a climate ripe for educational failure. For example, American Indian students who have graduated from college do not report having been encouraged to go to college by their teachers (Davis, 1992). Tracking is reinforced because of the reality of racism in the post-high school job market. Additionally, minority students were disadvantaged because of the emphasis on textbook instruction that required a high level of English proficiency (Deyhle, 1992).

Recent research on American Indian dropouts illustrates how secondary students give up on an education that they do not see as relevant to their lives. Deyhle (1992) quotes an American Indian student:

The way I see it seems like the whites don't want to get involved with the Indians. They think we're bad. We drink. Our families drink. Dirty. Ugly. And the teachers don't want to help us. They say, "Oh, no, there is another Indian asking a question" because they don't understand. So we stop asking questions. (p. 24)

She quotes another student:

It was just like they [teachers] want to put us aside, us Indians. They didn't tell us nothing about careers or things to do after high school. They didn't encourage us to go to college. They just took care of the white students. They just wanted to get rid of the Indians. (pp. 24-25)

Secada (1991) reports meeting high school mathematics teachers who did not want anything to do with LEP students and quotes a teacher as saying "I was trained to teach mathematics, not to teach *those* students" (emphasis in original, p. 35). The U.S. Secretary of Education's Indian Nations at Risk Task Force found that Indian students are faced with "an unfriendly school climate that fails to promote appropriate academic, social, cultural, and spiritual development among many Native students" (Indian Nations at Risk, 1991, p. 7). The Task Force set a goal that "by the year 2000 all schools will offer Native students the opportunity to maintain and develop their tribal languages." Deyhle and Secada's findings also reinforce another recommendation of the Indian Nations at Risk Task Force on the need for high quality teachers of Native students with special training. Of course, that special training needs to include training in dealing with LEP students, such as knowledge of bilingual education and teaching English as a second language, and teacher certification requirements need to reflect that need.

Today, about one third of American Indian students drop out of school with the Hispanic dropout rate not far behind (Indian Nations at Risk Task Force, 1991). The Navajo Area Dropout Study (Brandt, 1992; Platero et al., 1986), a very extensive study performed on the largest Indian reservation in the United States, showed that unsuccessful Navajo students perceived language problems as only a small part of the reason they were unsuccessful in school (see Table 1). Students who said they planned to drop out of school had similar responses. Thirty-seven percent of students who planned to drop out were bored with school while 29 percent planned to drop out because they had been flunked. Only eight percent gave academic failure as a reason. Twenty-four percent of the school administrators reported students dropped out of school because they were not interested in education (see Table 2).

However, even though students do not perceive language as a major reason for their lack of school success, Deyhle (1992), in interviewing dropouts and observing classrooms, found that many Navajo and Ute students did not have the academic language skills, specifically reading, to be able to do the typical type of classroom work required in class—reading the textbook and doing questions at the end of the chapter. This common type of classwork tends to bore students when they have the academic language skills to perform it, but it is doubly boring when students must sit quietly at their desks doing nothing because they cannot read well enough to do the assignment. Typically, the extra remedial help this type of student gets in special education and Chapter 1 classrooms breaks the content down into smaller pieces and allows students more time to complete it. This type of instruction can increase student boredom and pull students out of mathematics and science classes to take remedial reading classes (Savage, 1987; Smith, 1992).

Table 1

Navajo School Leavers' Reasons For Dropping Out

1. Bored with school	20.5%
2. Problems with other students	15.5%
3. Retained in grade due to absenteeism	14.2%
4. Pregnancy/marriage	9.6%
5. Problems with teachers	7.8%
6. Legal problems, arrest, etc.	7.3%
7. Substance/alcohol abuse	7.3%
8. To help family	7.3%
9. Disciplinary problems	5.9%
10. Academic failure	5.9%
11. Older than the other students	5.5%
12. Poor transportation	3.2%
13. Language problems	1.8%
14. Medical reasons	1.8%
15. Work	1.4%
16. Other	3.7%

Sources: Brandt, 1992, p. 57; Platero et al., 1986, p. 73.

Table 2
School Administrators' and Staff Opinions on What Causes Navajos to Drop Out

1. Lack of parent/family support and encouragement	38.4%
2. Academic problems and performance	29.1%
3. Home and family problems, home duties	25.6%
4. Lack of interest in education	24.4%
5. No incentive to finish; curriculum does not meet students needs	18.6%
6. Behavioral problems/attendance policy/travel distance	16.3%
7. Family movement/seasonal work	15.1%
8. Lack of teacher/staff support	11.6%

9. Poverty and other economic reasons	9.3%
10. Alcohol/drug abuse	7.0%
11. Health/pregnancy	3.5%

Sources: Brandt, 1992, p. 57; Platero et al., 1986, p. 61.

Any program to improve the instruction of LEP minority students must go beyond mechanical aspects of language and instruction to deal with the Eurocentric nature of American schooling that historically has devalued non-European, non-white cultures. Minority students who refuse to or cannot assimilate and who leave school "are described as deviant, dysfunctional, or deficient because of individual, family, or community characteristics" and are perceived as failures by whites (Deyhle, 1992, p. 25). Dropouts say school is "boring, teachers don't care, and school will not help them with what they want to do in life" (Deyhle, 1992, p. 25, paraphrasing LeCompte, 1987).

Reyhner (1992), in a review of school-based reasons for why American Indian students drop out of school at twice the national average, identifies seven areas of needed change: large impersonal schools, uncaring and untrained teachers, passive teaching methods, inappropriate curriculum, inappropriate testing and student retention, tracked classes, and lack of parental involvement. All these areas need to be addressed in order to improve the success rate for LEP students. However, this paper will focus on teacher-related instructional and curricular issues for mathematics and science—specifically, the areas of teacher training, teaching methods, and curriculum content. The first task for teachers is to learn how to motivate minority students; this goes beyond a simple "grabber," or anticipatory set, to providing students with classroom tasks that are intrinsically of interest to them. The second task is to provide instructional support so that students can understand the content being presented. Choosing meaningful content itself is the third task.

The state preconferences for the 1992 White House Conference on Indian Education also indicated a need for a holistic approach to American Indian education (Reyhner, 1991b). A holistic approach gives meaning to content and integrates together the various areas such as mathematics and science taught in schools. Considerable support is being given to whole language approaches to Indian education that support the use of thematic units at the secondary level. These units have been described by McCarty and Schaffer (in press) based on the work of Freeman and Freeman (1988) as an "explorer curriculum."

Thornburg and Karp (1992) put forward a similar "cognitive apprenticeship" model for mathematics and science instruction that includes modeling, scaffolding, evaluating, and peer collaborative strategies. "Modeling is a strategy that involves demonstrating the steps to accomplish a task [for example, a science experiment]—while verbalizing the thinking process accompanying the steps and why it might be done that way" (p. 167).

"Scaffolding is the term used to describe the support offered by the teacher on those aspects of the task the student cannot independently accomplish" (Thornburg and Karp, 1992, p. 167). Scaffolding involves linking the new material in some way to the students' prior knowledge and is also described by the authors as "supported practice." Knowledge of the students' home language and culture, by greatly expanding the teacher's awareness of the prior experiences that the student brings to the classroom, exponentially expands the teachers ability to provide LEP students scaffolding.

"Evaluation is part of the learning process where the learner reviews the strategies used in the attempt to master presented tasks, facilitating the learner's awareness and control of what is learned" (Thornburg and

Karp, 1992, p. 167). This is best done as a student-teacher dialogue rather than as a paper and pencil test. In collaborative peer groups, the three strategies described above "are used by the students to role play the expert and novice during task activities" (p. 167). Thornburg and Karp also emphasize students being explorers and emphasize the value of students working together in language development.

Another cross-curriculum approach that is finding renewed widespread acceptance for all students is cooperative (also called group or collaborative) learning. Human beings are social beings and the common practice of having students typically work alone goes against human nature. Glasser (1986), a psychiatrist, has pointed this out as a major reason for high school students' lack of interest in school. Beyond the obvious benefits of socializing, for LEP students, cooperative learning allows them to practice the English they are learning and to take advantage of peer tutoring. Hirst and Slavik (1990) and Thornburg and Karp (1992) give examples of how cooperative learning can be used with LEP students.

A third area of concern is the use of the LEP students' native language. Littlebear (1990) eloquently expresses the emotional attachment of an American Indian to his Northern Cheyenne language and how that language helps stabilize American Indian families. Diaz, Moll, and Mehan (1986) report research on Hispanic students that shows that teachers who do not have access to their students' native language cannot assess how much those students are learning. The students learned much more through reading an English text than they could express in the new language they were learning. A monolingual English speaking teacher could severely underestimate the progress of these students. A knowledge of the students' home culture can avoid the unintentional giving of offense to students and allow teachers to capitalize on how these students have "learned to learn" at home (Swisher and Deyhle, 1987, in press). While considerable research indicates that immersion "all-English" approaches can work with LEP students, the more knowledge that teachers have of the students' home language and culture, the better those teachers can respond to both the academic and nonacademic needs of their students.

Reyhner (1991a) gives a general overview of the knowledge base that teachers of American Indian LEP students need to know beyond the typical preparation teachers receive in education programs today. The authors elaborate on these principles for the specific curriculum areas of mathematics and science.

American Indian Mathematics Research

LEP students often experience difficulties in learning mathematics that have little to do with difficulties in processing mathematical ideas. When these LEP students are from different cultures, speak languages other than English as their primary language, and have preferred differences in cognitive processing, the typical approach to organized mathematics instruction observed in American classrooms today is inappropriate. An ethnomathematics approach to the curriculum is a means of addressing this concern. Both ethnomathematics and ethnosience emphasize the cultural content of the fields.

Issues in teaching mathematics to American Indian and other ethnic minority students center on the students' language processing and cultural orientation. The influence of language and culture on a bilingual student's learning of mathematics has been investigated by a number of researchers. Leap et al. (1982) observed that American Indian students' errors in mathematics problem solving were owing to the use of American Indian language mathematics-based problem solving strategies rather than inaccurate mastery of Western mathematics skills. A review of studies of mathematics learning among a variety of non-Western cultures indicated that indigenous peoples are often unable to solve mathematical problems that are not perceived as culturally relevant (Saxe, 1982). For example, the abstract addition of 37 and 14 is meaningless

to some non-Westerners. It would be more meaningful to restructure the problem as the addition of 14 horses to 37 horses in an American Indian community where horses are an important part of life.

Davison and Schindler (1988) identified three areas in which native students have difficulty in learning mathematics: language, culture, and learning modality. It is too simplistic to attribute minority students' difficulties in learning mathematics to any one factor alone. For example, minority students perform very poorly on standardized tests from the third or fourth grade on, although in the early years their performance is closer to average (Leap, 1988; De Avila, 1988).

Standardized group tests, by their very nature, place great importance on language skills, especially reading. A student who does not read well and has limited mastery of English is at a serious disadvantage. Thus it is clear that LEP students will automatically score low on standardized tests of mathematics and science. LEP students from the majority culture are subject to pressure to succeed by compensating for these deficiencies. Minority students typically do not receive such pressure because parents often do not have either the academic orientation or the academic knowledge to help their children. Furthermore, minority students are often not motivated by test taking. They find the questions irrelevant to their interests, and many do not respond to them seriously. This problem signals the need for test questions that students are willing to treat seriously. Finally, minority students sometimes perform poorly on tests because they do not understand mathematical processes. Such understanding usually comes through the use of manipulatives and visuals. In short, in competing with mainstream students on standardized tests, minority students are often disadvantaged through an interplay of English language deficiency, cultural dissonance between home and school, and inappropriate and excessively abstract instruction.

Methodology and Findings of Crow Indian Studies

Earlier reports (Davison and Schindler, 1986; Schindler and Davison, 1985) discuss the potential impact of the study of Crow/English language mathematics concepts and vocabulary. It should be noted that the spoken fluency rate of the Crow language has been high among the adult Crow reservation population. Read (1978) reported that nearly 80 percent of Crow Indian children have been identified as fluent speakers of the Crow language. Davison and Schindler explored the relationship between the acquisition of mathematics concepts in the English language and in the Crow language and documented the existence and use of mathematics vocabulary in the Crow language by surveying Crow Indian adults and children from several communities on the reservation. Although all of the students interviewed were classified as bilingual, one result of years of schooling Crow Indian children in the English language appears to be the loss of much of the Crow language's technical vocabulary. For example, only one of the children interviewed could count beyond 20 in the Crow language. Based on the interview data, it appeared that Crow mathematical terms and operations were typically not used to help teach mathematics to these students.

From the survey, Schindler and Davison (1985) found that dominant Crow language speakers viewed Crow as the language of the home and English as the language of the school. Such a dichotomy makes it very difficult for educators to fulfill the objectives of bilingual education and to reduce cultural discontinuity between home and school. One intent of bilingual education is the use the students' mastery of the native language to assist in acquiring mastery of the English language. This happens, for example, through the use of both languages in introducing mathematical concepts. However, mastery of mathematical concepts in the Crow language would have to be developed more in the school before they could be used to facilitate the learning of the same concepts in English. The problem was made worse by the students seeing little or no use for the textbook-dominated mathematics they learned in school.

The problem of English language fluency has already been identified. When English is not spoken in the home, or when an Indian English dialect is spoken, classroom English is not reinforced outside the school (Leap, 1990, in press). In mathematics this means that English language mathematics vocabulary may not be used outside the classroom. In addition, confusion occurs when certain terms such as "factor" and "product" have specialized meanings in the mathematics classroom different from their regular English language meanings. Garbe (1985), in his work with Navajo Indians, suggested that the students were not getting enough instruction in technical mathematics vocabulary. He recommended that vocabulary to be mastered be clearly identified and that student performance in vocabulary be passed on to the teacher of the next grade. At Rock Point Community School, teachers working with the whole-school maintenance bilingual program collectively made up new words in Navajo to be equivalent to English mathematical and scientific terms (Reyhner, 1990).

Conclusions from Crow Indian Studies

Teachers should use students' past experiences with mathematical terms to help give the terms meaning in a mathematical context. The introduction of a new term should be carefully orchestrated through repetition in context and through saying it aloud and spelling it. The application of native culture situations to the mathematics classroom represents one way of helping native students see relevance of mathematics in their culture, and to use this connection as a means of teaching more mathematics. One project that is doing this is "Increasing the Participation of Native Americans in Higher Mathematics," in Oklahoma (Aichele and Downing, 1985). However, we find that many native students know little about their traditional culture since schools have historically been used to suppress traditional cultures and to assimilate Indians into the dominant culture. Thus an initial premise that cultural background can be used to facilitate the teaching of mathematics is suspect, but we have found that the interaction of native culture and mathematics ideas can be mutually reinforcing.

For example, Rosalie Bearcrane, who was a bilingual teacher at Crow Agency School, taught a sixth grade class about the Crow Indian reservation. She divided the map of the reservation into six equal rectangles and assigned each portion to a group within the class. Each group had to enlarge its portion of the map by a scale of 3:1 and then had to make a plaster relief model of the enlargement. The finished products were combined to form a table-sized relief map of the reservation. This task was motivating for the students, and taught them more about their native heritage while they learned more mathematics. In other situations, such culturally relevant phenomena as hand games, arrow throws, and bead loomwork have been used as a basis for stimulating classroom mathematics.

The example given above illustrates what may be termed an ethnomathematics approach to the curriculum. D'Ambrosio (1985) defines "ethnomathematics" as the mathematics needed by a particular subgroup of the population, be it an occupational group or a cultural group. Ethnomathematics includes curricular relevance, but is much more than building a curriculum around the local interests and culture of the learners. It must be understood in terms, not only of the traditional native culture, but also of its emerging identity, one that lives side by side with the mainstream culture. In this sense, an ethnomathematics approach to the curriculum will draw on traditional culture while focusing attention on the mathematics needed by these students in an integrated society. A curriculum perceived as irrelevant by native students cannot fulfill that objective. Whether the illustrations are traditional or modern, they must engage the students' attention and interest if the students are to be helped in understanding the important mathematical ideas.

Attention to the students' language mastery and perceived relevance of mathematics addresses just one

dimension of the students' difficulties with mathematics learning. We also need to consider the effect on the students of the method of presentation of the mathematics.

Research on American Indian Learning Styles

Typical mathematics learning materials, most often textbooks, are prepared on the assumption that all students learn mathematics in the same way. An examination of such resource materials indicates that the dominant mode of presentation of mathematics is abstract. However, evidence from research and observation indicates that Native students usually do not like a verbal, abstract style of mathematics learning and prefer familiar tactile and visual stimuli.

In a review of the literature on American Indian learning styles, Swisher and Deyhle (1987) conclude that Indian students "approach tasks visually, seem to prefer to learn by careful observation that precedes performance, and seem to learn in their natural settings experientially. . . . [They] come to learn about the world in ways that are different from mainstream students" (p. 350). Wauters et al. (1989) found that Alaskan students strongly prefer visual and tactile modes of learning. More (1989) warns against stereotyping native students through an overemphasis on learning style differences. Yet he recommends that teachers of native students "present new and difficult material in a visual/spatial/perceptual mode rather than a verbal mode" (p. 24). Rhodes (1990), in an investigation of the learning styles of Navajo and Hopi students, found dissonance between the learning styles of the students and the teaching styles of their teachers. The "watch me and do as I do" procedures used in traditional schooling appear to be less appropriate than a process of "watch me and try it when you feel comfortable with it." He asserts: "Once the teachers become more sensitive to the learning styles of the students, they can adapt . . . the implementation of the curriculum more to the student needs" (p. 37).

The research reviewed here presents a consistent picture of the American Indian learner as one who prefers mathematics to be presented through physical or visual stimuli. In the context of the discussion of American Indian learning styles, we should not overlook the caution sounded by Diessner and Walker (1989) that, to be competitive in pluralistic America, Indian students need to increase their English language and basic information achievement. This attention to American Indian learning styles is viewed not as an explanation for failure to learn abstract mathematics, but as an opportunity to enable this goal to be accomplished.

Geometry is the one branch of mathematics that stresses spatial rather than analytical approaches to mathematics and can be used to build on the visual strengths of American Indian students. Success in geometry is also related to a kinesthetic processing of the environment. For example, Davison and Schindler (1986) found that, when given the geometric attribute pieces containing the primary colors, four shapes, and two sizes, non-Indians classified primarily by color first. The Crow Indian students studied, on the other hand, mostly classified by shape first. This observation supports the notion that these Indian students' preferred style of mathematical processing was essentially kinesthetic.

Another project dealing with the way students learn mathematics is Math and the Mind's Eye, a National Science Foundation-funded project under the directorship of Gene Maier in Portland, Oregon. Maier (1985) points out that many people, in the Anglo as well as American Indian cultures, find mathematics devoid of meaning—nothing more than jargon and symbol manipulation. The result is mathematics underachievement, anxiety, and aversion. Many of the people who do succeed in post-school mathematics use sensory perception, models, and imagery. This is very different from the views of school mathematics described here. Maier's project stresses the use of manipulatives and activity methods in the middle grades. Certainly,

an emphasis on a hands-on approach to mathematics learning would help Indian students make more sense of the way mathematics is presented.

Curriculum designers are being made aware that not all students learn mathematics in the same way. Materials that place emphasis on the use of hands-on activities will help students whose primary learning mode is kinesthetic rather than abstract—although it can be argued that for real subject matter understanding, all students need to learn first from concrete experiences before they move to more abstract representations of those experiences. The use of a multisensory, activity-centered approach in working with Native students is one way of responding to their different learning styles. There is a clear suggestion that these students will be more successful when the presentation of mathematics material responds to their learning styles by being less abstract and more visual and tactile. This observation is supported by students' preference for geometric tasks, and suggests that they can succeed in English language mathematics so long as it makes sense in terms of the way they process information. Initially, the use of the native language is important as an aid to learning English language terminology; the continued successful learning of mathematics depends on students being able to process the ideas in a meaningful way. Accordingly, it appears that a teaching style that is more visual/sensory oriented would seem to be essential.

An example of a mathematics curriculum for American Indians that incorporates the extensive use of manipulatives in the early grades is the one at Rock Point Community School in Arizona. Students first use special counting blocks that come both individually and pre-grouped in sets of two through ten to perform mathematical calculations. Only after being talked through the problems using blocks in both Navajo and English do the students advance to pictures of blocks on worksheets, and only after using these visual representations of blocks do they move on to abstract calculations using numbers alone. The Rock Point curriculum is based on the now out-of-print Stern Mathematics program that was published by Houghton Mifflin (see also Stern, 1949). The success of this multisensory approach that stresses understanding is seen in the mathematical attainment of Rock Point seniors who, on average, score at or above national averages on the mathematics portion of the California Test of Basic Skills (Reyhner, 1990).

Research Combining Language Activities with Mathematics

Davison and Pearce (1988) report how English and mathematics are usually treated as two different subjects with teachers of mathematics rarely seeing part of their job as helping students improve their language skills. This hurts all students, but puts LEP students at an extreme disadvantage. As indicated previously, it is not language but motivation that must be dealt with first with LEP students who come from dominated minorities. Teachers cannot assume their students have parents who have programmed their children about the importance of schooling—a situation that can lead to students learning in spite of poor instructional methodologies and curricula. Minority students must first be convinced about the importance of mathematics in their lives and their home culture. As Deyhle (1992) has indicated, it is not enough to hold out the possibility of higher-income employment. Groups such as the American Indian Science and Engineering Society have a variety of techniques that respect traditional Indian cultures and utilize role models and peer groups to increase student interest in math and science careers.

Pearce and Davison (1988) observed teachers using five methods to help students put mathematical concepts into language and to learn better (see Table 1). They note, in the best whole language tradition, that writing activities "are more valuable if students write for an audience other than just the teacher" (p. 8). This extended audience can include classmates, younger students, parents, and "mystery" friends.

Table 1
Examples of Methods for Putting Mathematics Ideas into Writing.

Method	Example
1. Direct Use	Copying information from the board, the text, or a worksheet.
2. Linguistic/Translation	Writing in a complete sentence the meaning of the formula $A = R^2$
3. Summarizing/ Interpreting	Explaining how to solve a problem in students' words; keeping a journal (learning log) about what students have learned in class.
4. Applied Use	Having students write their own story problems.
5. Creative Use	Having students write a report on a mathematics project.

Source: Pearce and Davison (1988), p. 11.

Native American students who do well adding, subtracting, multiplying, and dividing, often fail when it comes to solving story problems that add a reading dimension to mathematics. This is one explanation of the downward trend in Indian student standardized test scores in the upper elementary grades where solving story problems becomes more important. Having students start in the primary grades to write their own story problems relevant to the world around them will help them understand what story problems are all about, will help develop their language skills, and will give them an understanding of the real world applications of mathematics. A teacher can ask each student in class, individually or in groups, to write and illustrate a story problem to fit a given problem such as $6/3 = 2$ and then ask each student to read and solve the story problem for the rest of the class. One Billings, Montana, teacher then had her students glue their sheets together on a bulletin board in such a way that, at the end of the school year, each student had his or her own math storybook to take home for review during the summer.

A coordinated program to lead LEP students to success with story problems starts with leading students to observe how mathematics and science are used all around them and to discuss and write about the importance of mathematics. Second, students should discuss and write about the meaning of the mathematical process they used to arrive at an answer. Third, students are asked to explain, orally and in writing, the steps they used to solve a textbook-type mathematical problem using manipulatives. Fourth, students are shown a similar problem with just manipulatives and no numbers. Fifth, they are asked to describe the steps they used to complete the problem. Sixth, students make up a problem in which manipulatives may be used. Finally, the students are asked to make up a story problem that uses the same mathematical operation they have dealt with in the preceding two activities.

Davison and Pearce (1992) provided seventh and eighth grade Crow Indian students with a variety of experiences to help overcome mathematics deficiencies. Students were introduced to a manipulative approach to fractions and logic activities and had to describe these tactile experiences in writing. In addition, assigned activities included creating related story problems and having them solved by their peers. Most of the students responded positively to this approach.

Davison and Pearce (1988) gave examples of their language development activities including journal writing, vocabulary development, writing story problems, letter writing, and mini-mathematical projects. Each student kept a personal mathematics journal that served as a means of communication between the student and teacher. For example, in their journals students wrote their own definitions of new mathematics terms they learned. In groups, students wrote story problems as a culminating activity after sample problems were worked through in class. Students then exchanged the problems they wrote. Students also wrote letters to someone else explaining a rule or concept they were learning. The mini-mathematics project was a public opinion graphing project that involved students coming up with a topic of interest, developing a questionnaire, interviewing people, and tallying, tabulating, and reporting their results in writing, which were then shared with the rest of the school.

This integration of mathematics, reading, writing, speaking, and listening activities fits the whole language approach to instruction currently being advocated by a number of educators for all children. The tasks students were assigned, including journal writing, descriptions, explanations of procedures used, and creation of problems, are typical of whole language classrooms. Analysis of observational data indicated that these students, who were reluctant writers, were now more willing to write. Their performance in both language and mathematics improved—in language because they were writing more and in mathematics because they showed some understanding of the processes they were studying (Davison and Pearce, 1992).

The focus of the above studies was to determine how familiar situations and tactile/visual approaches integrated with systematic language activities help students improve both their level of language functioning and mathematics performance. An ethnomathematics solution to the problem calls for the use of the familiar to help students learn the mathematics needed for success in our society and be motivated to work to accomplish that goal.

Research on Science Education for LEP students

The issues discussed above for mathematics instruction are similar to those for science instruction. In fact, the joining of mathematics and science instruction can lead to giving both greater meaningfulness for LEP and other students. In this section three general approaches are discussed. The CALLA ESL approach to content area instruction is discussed first. Then ethnoscience-inquiry and language study approaches are discussed.

The CALLA Approach

Ovando and Collier (1985, p. 205) see the principles of mathematics and science lending "themselves to demonstrations and hands-on experiences." They cite Cummins on how the use of mathematics manipulatives and hands-on science activities can be a bridge for students to move from context-embedded conversational language skills to context-reduced classroom (academic) language skills. Chamot and O'Malley's (1986) Cognitive Academic Language Learning Approach (CALLA) details strategies for bridging the gap between conversational English proficiency for LEP students and cognitive academic proficiency using mathematics, science, and social studies. The goal of their model is to mainstream students into the regular curriculum. But as indicated at the beginning of this paper, unless the mainstream curriculum is modified to reflect the cultural background of LEP students, many LEP students will continue to not find success. Chamot and O'Malley view their program as a bridge for LEP students to move from conversational to academic proficiency in English and thus to school success. They see hands-on science,

then problem solving mathematics, and finally social studies as the means of introducing content-based instruction to LEP students. The program introduces students to metacognitive, cognitive, and social-affective strategies.

As Binet suggested for special education students at the turn of the century, students are taught to learn how to learn (Gould, 1981). What Chamot and O'Malley fail to deal with in any depth are both the cultural and personal aspects of how children learn (see, for example, Swisher and Deyhle, 1987, in press) and the cultural component of content area instruction. Gould gives excellent examples in his book *The mismeasure of man* (1981) of how science is influenced by nonscientific ideas. Deyhle (1992, p. 30) describes how students who experience "minimal individual attention or personal contact with their teachers" translate that into an "image of teacher dislike and rejection." Deyhle gives examples of a science teacher's attempt to encourage Navajo students that was perceived as a put down by them, and of a student who returned to a lower tracked math class where she was the best student because of the isolation and struggle she felt in an otherwise all-white high track class. The need for class sizes that allowed teachers to give individual attention to students was also found by Binet in his study of special needs students at the turn of the century (Gould, 1981).

Ovando (in press) discusses the use of Chamot and O'Malley's CALLA in science instruction, emphasizing the need for teachers "well versed not only in science content, process, and activities but also in English as a Second Language (ESL) and bilingual teaching principles and methods" (p. 228). Reyhner (1991a) also emphasizes this extended professional background for teachers of LEP students. However, Chamot and O'Malley (1986) give hardly more than lip service to the importance of incorporating the student's cultural background into science instruction. Their comment on this subject in their science section is limited to:

The naive belief systems about how the world works and reasons for scientific phenomena may, in the case of LEP students, be related to their cultural background. In the area of science, as in social studies, the cultural background of the students can be used effectively for instruction. One way of incorporating students' home culture into science lessons is to have students investigate the scientific properties of familiar items from their own culture. (p. 28)

This is a very superficial treatment of the subject that could lead to real classroom problems. One needs to be very careful about the "naive" beliefs of any culture toward the way the world works. The lesson examples Chamot and O'Malley give, while incorporating research on language acquisition, follow a behavioristic model (see Smith, 1992) that fails to incorporate the cultural, affective, and social aspects of human learning that have been discussed in this paper. Their model is viewed as a bridge for LEP students to cross into the mainstream curriculum. They do not deal with the students who might not want to cross that bridge or who may later want to recross it.

Ethnoscience-Inquiry Approaches

Brown (1979) corroborates Cummins' (1989) claim about the predominance of transmission/textbook teaching methodology in the United States. He writes that, despite the post-Sputnik attempts to reform American science education, "teachers very largely continued to teach in their old styles, demanding that students continue as passive recipients of whatever the text or teacher purported to be true and necessary knowledge" (1979, p. 229). He describes how he replaced traditional lectures, demonstrations, and films with school science club-type activities and began with a study of the ecology and natural history of the local area. Similar to Cummins' "guide and facilitator," Brown saw his role as "to advise, question, and

guide the students' work and organize his students into small cooperative education groups" (1979, p. 230). He found that "students learned and, more importantly, they learned how to direct their own learning" (1979, p. 231).

Guthridge (1986) gives a practical example of this in an Eskimo school in Gambell, Alaska, where the science curriculum revolves around future problem solving. Guthridge details an activity-oriented classroom, similar to the explorer classroom previously described, where students working in groups start with environmental or other problems, or just student questions. Then, using the scientific method, students make hypotheses, control for variables, collect and record data systematically, and draw conclusions from their data.

Examples of materials to go with these type of lessons have been produced by a number of bilingual education programs. For example, the maintenance Navajo-English bilingual program at Rock Point, Arizona, has produced books on Navajo farming (Bingham and Bingham, 1979, 1984) and making a living raising livestock. The Hualapai Bilingual Program at Peach Springs, Arizona, has produced books on cattle ranching (Watahomigie et al., 1983) and the scientific and traditional use of native plants (Watahomigie, Powskey, and Bender, 1988).

Language Study Approaches

A final area of culturally appropriate scientific study for LEP students is, of course, language itself. Hale, a linguist, writes,

The study of language should form a part of curriculum. Linguistic science has the advantage over the other sciences that the data relevant to it are immediately accessible, even to the youngest of students, and it requires a minimum of material and equipment. (1980, p. 3, as quoted in Ovando, in press, p. 235)

Through the scientific study of language, not only can teachers model the scientific method of inquiry, but also students can become more sophisticated in their knowledge and use of language.

Conclusions and Recommendations

Many LEP students who are not succeeding in school do not see schooling as something important in their lives. This means both that school is a white institution for white students and that they either do not see the jobs available that the curriculum is preparing them for or do not see that the jobs available require a high school education. For example, Deyhle (1992), in her study of Navajo and Ute students, found high school and nonhigh school graduates working in the same type of jobs.

The capacity of LEP students to learn mathematics and science is influenced by language, culture, and learning style. However, the methods by which mathematics and science are typically presented do not take into consideration these factors. For example, textbooks are typically written for white middle-class America and present mathematics as an essentially abstract subject and science as information to be memorized. Many textbook series now make reference to the use of tactile and visual aids and experiments and many teachers, especially at the primary level, use manipulatives in their classroom. However, few teachers succeed in helping students develop mathematical abstractions and scientific principles from these hands-on activities. To learn mathematics and science successfully, many LEP students need a more multisensory approach to mathematics than is usually encountered in schools.

While we advocate a more hands-on curriculum, the LEP student educator must recognize the reality of having to prepare his/her students to deal with the ubiquitous textbook:

The subjective observation that the student "can't read the textbook" is based on the incorrect notion that they should be able to read the material independently. Assignments are given; students do poorly in their attempts to read the material; the teacher is disappointed; the students are frustrated. (Herber, 1978, p. 17 as quoted in Ovando, in press, p. 232)

Ovando (in press) and Pearce (in press) give a number of strategies that can be used to help LEP students deal with extracting information from science textbooks. Both emphasize going beyond behavioristic and phonics-oriented approaches to a comprehension focus that helps students use their prior knowledge to extract meaning from text. Rather than getting a student to memorize and recall science terminology and definitions, the focus is on getting students to express in their own words the scientific knowledge they have learned through nontextbook learning experiences. Using these strategies expands the already expanded role of the science teacher beyond being an ESL and bilingual educator to also being a reading teacher. The tremendous breadth of background needed for the successful teacher of LEP students begins to explain the historical lack of success educators have had with LEP students.

Based on the research reviewed in this study, including the authors' own studies, we make the following recommendations to improve the education of LEP students in mathematics and science.

Recommendation 1: Teachers must relate their mathematics and science instruction to the out-of-school life of their students. By doing this, the teacher constructs a "bridge" that LEP students can cross in order to become successful in mainstream science classes. Ovando (in press) emphasizes the need for that bridge to allow back and forth passage. He quotes Scribner and Cole:

Changes in textbooks, curricula, and teaching techniques are all needed and important, but they cannot be counted on to bridge the gulf between school and practical life by themselves. A two-way movement is necessary here. The first, which is already under way in some experimental schools, is to move everyday life into the school so that subject matter and activities deal with some of the aspects of social and physical reality that the pupils confront outside of school.

The second has been little attempted. The techniques of the modern school need to be introduced into the context of recognized practical problems. Education must be stripped from the schoolroom and made instrumental in traditional settings. (Scribner and Cole, 1973, p. 558, as quoted in Ovando, in press, pp. 225-26)

Continuing the bridge metaphor, if students see that crossing the bridge will permanently separate them from their friends and family, and if parents see that they will lose touch with their children after they cross the bridge, then many students will refuse to cross that bridge. Cultural incorporation, based on the students' home culture, into both curriculum and teaching methods can make crossing the bridge less of a break with home and community. It also means that the bridge can be recrossed again and again as students draw on their knowledge of their community and culture. That continued recrossing can bring badly needed family and other human values into the fields of science and mathematics.

Recommendation 2: The implementation of ethnomathematics and ethnosience can help teachers relate those subjects to their students' out-of-school lives. Ovando (in press) cites the 1976 American

Association for the Advancement of Science's *Recommendations for the improvement of science and mathematics for American Indians* (Green and Brown, 1976). That document calls for an ethnoscience approach, bilingual instruction, and the recruitment of Indians into science careers. Ethnoscience involves the awareness of how different cultures classify natural phenomena and have different scientific world views. It also involves, as Brown (1979) suggests, the study of the local environment along with a recognition of the complex knowledge traditional cultures, such as American Indian cultures, have of their physical and biological surroundings.

Recommendation 3: Teachers must use teaching methodologies that "contextualize" the subject matter they teach. The abstract, decontextualized teaching of mathematics and science has affected the ability of many LEP students to experience school success. Students who speak non-English languages need more attention to be paid to mastery of mathematics and science terminology in their native language and need to relate this knowledge to the mastery of English language mathematics and science vocabulary. Wherever possible, mathematics and science concepts should be presented in a culturally relevant manner using situations in which the students have interest and familiarity. Above all, the presentation of mathematical and scientific concepts needs to be consistent with how students learn. The use of a multisensory approach that includes visual and tactile experiences assists LEP students to form meaningful images. Progress in these three areas will contribute to more successful learning of mathematics and science by LEP students.

Based on their review of research the authors advocate a holistic inquiry-based curriculum for LEP students that integrates mathematics and science with the language arts curriculum. The use of thematic units, such as one observed at Wyoming Indian Schools in their junior high, can help maintain student motivation while incorporating mathematical and scientific information in a meaningful context. The unit was on the Iditarod Sled Dog Race. Students followed the race in the daily newspaper and read *Julie of the wolves* (George, 1972), a juvenile novel set in Alaska. Students applied the mathematics they were learning by keeping track of the distances that sleds were covering each day, while science students studied Alaska's geography and climate.

Recommendation 4: Teachers need to be concerned about affective factors in their classrooms. They need to care about the whole student, not just the student's academic performance. They must take the time and effort to learn about their students' home cultures. As Deyhle's (1992) dropout study indicates and Reyhner's (1992) review of research corroborates, the students perception of the teacher as "caring" is a critical factor in keeping American Indian students in school. The international study by Beckum et al. (1991) supports this recommendation that the affective factor is the most important determinant of successful teaching. They quote a New York City teacher to the effect:

It came to me between the 10th and 15th year of teaching. Between the 10th and 15th year of teaching I discovered that what was needed for these children was not an emphasis on the academic but a meaningful interaction with mature adults. The relationship with a stable, mature adult is most important. (p. 45)

Recommendation 5: Teachers of mathematics and science need to provide writing and other language development activities for their LEP students. Teachers need to build language supports to help students understand the language in word problems and textbooks and to begin to use English as a vehicle for thought. Steps involved in solving word problems must be made explicit. It is critical that language factors be addressed by having students hear, speak, and write much more English language mathematics and science through appropriately guided instruction.

References

- Aichele, D., and Downing, C. (1985). *Increasing the participation of Native Americans in higher mathematics*. Project funded by the National Science Foundation.
- Beckum, L. C., Garcia, O., Otheguy, R., Zimmy, A., Horend, I, Perry, P., Lord, E., and Rollett, B. (1991). Identifying a knowledge base for teaching multicultural, multilingual students: An international study. In M. C. Pugach, H. H. Barnes, and L. C. Becum, *Changing the practice of teacher education: The role of the knowledge base*. Washington, D.C.: American Association of Colleges for Teacher Education.
- Brandt, E. A. (1992). The Navajo Area Student Dropout Study: Findings and implications. *Journal of American Indian Education*, 31 (2), 48-63.
- Bingham, S. and Bingham, J. (1979). *Navajo farming*. Rock Point: Rock Point Community School.
- Bingham, S. and Bingham, J. (Eds.). (1984). *Between sacred mountains: Navajo stories and lessons from the land*. Tucson: University of Arizona.
- Brown, A. (1979). The cross-over effect: A legitimate issue in Indian education? In *Multicultural education and the American Indian*. Los Angeles: American Indian Studies Center, University of California, Los Angeles.
- Cantieni, G., and Tremblay, R. (1979). The use of concrete mathematical situations in learning a second language: A dual learning concept. In H. T. Trueba and C. Barnett-Mizrahi, *Bilingual multicultural education and the professional: From theory to practice*. Rowley: Newbury House.
- Chamot, A. U., and O'Malley, J. M. (1986). *A cognitive academic language learning approach: An ESL content-based curriculum*. Rosslyn: National Clearinghouse for Bilingual Education.
- Cummins, J. (1989). *Empowering minority students*. Sacramento: California Association for Bilingual Education.
- D'Ambrosio, U. (1985). *Socio-cultural bases for mathematics education*. São Paulo, Brazil: Universidade Estadual de Campinas (Unicamp).
- Davis, J. (1992). Factors contributing to the post-secondary achievement of American Indians. Unpublished master's thesis, Eastern Montana College, Billings.
- Davison, D. M., and Pearce, D. L. (1988). Using writing activities to reinforce mathematics instruction. *Arithmetic Teacher*, 35 (8), 42-45.
- Davison, D. M., and Pearce, D. L. (1992, Spring). The influence of writing activities on the mathematics learning of American Indian students. *The Journal of Educational Issues of Language Minority Students*, 10 (Special Issue 2), 147-57.
- Davison, D. M., and Schindler, D. E. (1986). Mathematics and the Indian student. In J. Reyhner (Ed.), *Teaching the Indian child: A bilingual/multicultural approach*. Billings: Eastern Montana College.

- Davison, D. M., and Schindler, D. E. (1988). Mathematics for the Native student. In H. Gilliland and J. Reyhner, *Teaching the Native American*. Dubuque Kendall/Hunt.
- De Avila, E. A. (1988). Bilingualism, cognitive function, and language minority group membership. In R. R. Cocking and J. P. Mestre, *Linguistic and cultural influences on learning mathematics*. Hillsdale: Erlbaum.
- Deyhle, D. (1992). Constructing failure and maintaining cultural identity: Navajo and Ute school leavers. *Journal of American Indian Education*, 31 (2), 24-47.
- Diaz, S., Moll, L., and Mehan, H. (1986). Sociocultural resources in instruction: A content-specific approach. In California Office of Bilingual Bicultural Education, *Beyond language: Social and cultural factors in schooling language minority students*. Los Angeles: California State University.
- Diessner, R., and Walker, J. L. (1989). A cognitive pattern of the Yakima Indian students. *Journal of American Indian Education*, 28 (4), 84-88.
- Freeman, Y, and Freeman, D. (1988). *Bilingual learners: How our assumptions limit their world*. Occasional Paper No. 18. Program in Language and Illiteracy, College of Education, University of Arizona, Tucson.
- Garbe, D. G. (1985). Mathematics vocabulary and the culturally different student. *Arithmetic Teacher*, 33 (2), 39-42.
- George, J. C. (1972). *Julie of the wolves*. New York: Harper and Row.
- Glasser, W. (1986). *Control theory in the classroom*. New York: Harper and Row.
- Gould, S. J. (1981). *Mismeasurement of man*. New York: W. W. Norton.
- Green, R., and Brown, J. W. (1976). *Recommendations for the improvement of science and mathematics education for American Indians*. Washington, D.C.: American Association for the Advancement of Science.
- Guthridge, G. (1986, April). Eskimos solve the future. *Analog*, 67-72.
- Hale, K. (1980). Linguistics and local languages in a science curriculum for bilingual/bicultural programs. Massachusetts Institute of Technology. (unpublished).
- Herber, H. L. (1978). *Teaching reading in content areas*. 2d. ed. Englewood Cliffs: Prentice Hall.
- Hirst, L. A., and Slavik, C. (1990). Cooperative approaches to language learning. In J. Reyhner (Ed.), *Effective language education practices and native language survival* Choctaw: Native American Language Issues.
- Indian Nations at Risk Task Force. (1991). *Indian nations at risk: An educational strategy for action*. Washington, D.C.: U.S. Department of Education.
- Leap, W. L. (1988). Assumptions and strategies guiding mathematics problem solving by Ute Indian students. In R. R. Cocking and J. P. Mestre, *Linguistic and cultural influences on learning mathematics*.

Hillsdale: Erlbaum.

Leap, W. L. (1990). Written Ute English: Texture, construction, and point of view. In J. Reyhner (Ed.), *Effective language education practices and Native language survival*. Choctaw: Native American Languages Issues.

Leap, W. L. (in press). American Indian English. In J. Reyhner (Ed.), *Teaching American Indian students*. Norman: University of Oklahoma Press.

Leap, W. L., McNett, Jr., C., Cantor, J., Baker, R., Laylin, L., and Renker, A. (1982). *Dimensions of math avoidance among American Indian elementary school students*. Final Report. Washington, D.C.: American University.

LeCompte, M. D. (1987). The cultural context of dropping out: Why good dropout programs don't work. Paper presented to the American Association for the Advancement of Science, Chicago.

Littlebear, D. (1990). Keynote address: Effective language education practices and native language survival. In J. Reyhner, (Ed.), *Effective language education practices and native language survival*. Choctaw, OK: Native American Language Issues.

McCarty, T. L., and Schaffer, R. (in press). Language and literacy development. In J. Reyhner (Ed.), *Teaching American Indian students*. Norman: University of Oklahoma Press.

Maier, G. (1985). *Math and the mind's eye*. Project funded by the National Science Foundation.

More, A. J. (1989). Native Indian learning styles: A review for researchers and teachers. *Journal of American Indian Education*, 28 (4), 15-28.

Oakes, J. (1985). *Keeping track: How schools structure inequality*. New Haven: Yale University.

Ogbu, J. U. (1987). Variability in minority school performance: A problem in search of an explanation. *Anthropology and Education Quarterly*, 18 (4), 312-34.

Ovando, C. J. (in press). Science. In J. Reyhner (Ed.), *Teaching American Indian students*. Norman: University of Oklahoma Press.

Ovando, C. J., and Collier, V. P. (1985). *Bilingual and ESL classrooms: Teaching in multicultural contexts*. New York: McGraw Hill.

Pearce, D. L. (in press). Improving reading comprehension. In J. Reyhner (Ed.), *Teaching American Indian students*. Norman: University of Oklahoma Press.

Pearce, D. L., and Davison, D. M. (1988). Teacher use of writing in the junior high mathematics classroom. *School Science and Mathematics*, 88 (1), 6-15.

Platero, P. R., Brandt, E. A., Witherspoon, G., and Wong, P. (1986). *Navajo students at risk: Final report of the Navajo area dropout study*. Window Rock: Navajo Area Dropout Study.

Read, J. A. S. (1978). A sociolinguistic study of Crow language maintenance. Doctoral dissertation,

University of New Mexico, Albuquerque.

Reyhner, J. (1990). A description of the Rock Point Community School bilingual program. In J. Reyhner (Ed.), *Effective language education practices and native language survival*. Choctaw: Native American Language Issues.

Reyhner, J. (1991a). The challenge of teaching minority students: An American Indian example. *Teaching Education*, 4 (1), 103-112.

Reyhner, J. (1991b). The White House Conference: Is there hope for Indian education? *Journal of Navajo Education*, 9 (1), 10-12.

Reyhner, J. (1992). American Indians out of school: A review of school-based causes and solutions. *Journal of American Indian Education*, 31 (3), 37-56.

Reyhner, J. (in press). Adapting curriculum to culture. In J. Reyhner (Ed.), *Teaching American Indian students*. Norman: University of Oklahoma Press.

Rhodes, R. W. (1990). Measurements of Navajo and Hopi brain dominance and learning styles. *Journal of American Indian Education*, 29 (3), 29-40.

Savage, D. G. (1987). Why Chapter 1 hasn't made much difference. *Phi Delta Kappan*, 68, 581-84.

Saxe, G. B. (1982). Culture and the development of numerical cognition: Studies among the Okasapmin of Papua New Guinea. In C. J. Brainerd (Ed.), *Children's logical and mathematical cognition*. New York: Springer-Verlag.

Schindler, D. E., and Davison, D. M. (1985). Language, culture, and the mathematics concepts of American Indian learners. *Journal of American Indian Education*, 24 (3), 27-34.

Scribner, S., and Cole, M. (1973). Cognitive consequences of formal and informal education. *Science*, 182, 553-58.

Secada, W. G. (1991). Diversity, equity, and cognitivist research. In E. Fennema, T. P. Carpenter, and S. J. Lamon (Eds.), *Integrating research on teaching and learning mathematics*. Albany: State University of New York.

Smith, F. (1992). Learning to read: The never ending debate. *Phi Delta Kappan*, 73 (6), 432-41.

Spindler, G. D. (1987). Why have minority groups been disadvantaged by their schools? In G. D. Spindler (Ed.), *Education and cultural process: Anthropological approaches*. Prospect Heights: Waveland.

Stern, C. (1949). *Children discover arithmetic: An introduction to structured arithmetic*. New York: Harper.

Swisher, K., and Deyhle, D. (1987). Styles of learning and learning of styles: Educational conflicts for American Indian/Alaska Native youth. *Journal of Multilingual and Multicultural Development*, 8 (4), 345-360.

Swisher, K., and Deyhle, D. (in press). Adapting instruction to culture. In J. Reyhner (Ed.), *Teaching*

American Indian students. Norman: University of Oklahoma Press.

Thornburg, D. G., and Karp, K. S. (1992, Spring). Lessons learned: (Mathematics + science + higher order thinking) x second-language learning = ? *The Journal of Educational Issues of Language Minority Students*, 10 (Special Issue), 159-84.

Watahomigie, L., Powskey, M., and Bender, J. (1982). *Ethnobotany of the Hualapai*. Peach Springs: Hualapai Bilingual Program, Peach Springs School District No. 8.

Watahomigie, L., Powskey, M., Bender, J, Uqualla, J., and Watahomigie, Sr., P. (1983). *Waksi: Wich Hualapai cattle ranching*. Peach Springs: Hualapai Bilingual Program, Peach Springs School District No. 8.

Wauters, J. K., Bruce, J. M., Black, D. R., and Hocker, P. N. (1989). Learning styles: A study of Alaska native and non-native students. *Journal of American Indian Education* 28 (4), 53-62.

Wax, M. L., Wax, R. H., and Dumont, R. V. (1989 [1964]). *Formal education in an American Indian community: Peer society and the failure of minority education*. Prospect Heights: Waveland.