MATHEMATICS LESSON INTERACTIONS AND CONTEXTS FOR AMERICAN INDIAN STUDENTS IN PLAINS REGION SCHOOLS:

AN EXPLORATORY STUDY

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EXECUTIVE SUMMARY

The achievement gap between some groups of students is a regional and national concern. In an effort to reduce the gap and improve the quality and outcomes of mathematics education for American Indian students, a variety of mathematics initiatives have been adopted in classrooms and schools across the nation. This study focuses on three different approaches to mathematics teaching and the current and potential impact of each approach on classroom practice and American Indian student achievement.

According to federal and state policy and educators' principles of best practice, opportunities to learn ought to emphasize not only challenging academic standards but also the varying ways in which people of different cultures understand, value and use knowledge. Educators working with American Indian students need information to know how to consider and sustain cultural responsiveness as well as how to make sure all students reach high levels of proficiency in mathematics. To address this need, in 2003 McREL formed a research partnership with researchers, regional teachers, and local and state education leaders. The purpose of the partnership is to conduct meaningful, methodologically sound research on mathematics education and, by doing so, provide a region-specific infrastructure and set of resources to practitioners for developing and weighing different possibilities for teaching mathematics to American Indian students.

This study was intended to identify classroom and student variables of interest and develop instruments for their measurement. A comparative case study was conducted on six mathematics lessons as implemented from one of three adopted approaches: Cognitively Guided Instruction (CGI), Success for All (SFA) MathWings, or Saxon Math. In each lesson, American Indian students comprised a substantial subgroup of students in the class or the whole class. Key results indicated that level of cognitive demand in mathematical tasks and teacher's questions distinguished the lessons taught from the different approaches.

The extent to which students engaged in problem solving tasks and were encouraged to engage in mathematical reasoning, conjecturing and inventing was highest in the CGI lessons, lower in the SFA MathWings lessons, and lowest in the Saxon Math lessons. Although telling statements dominated the teachers' talk in all six lessons, the teacher's talk in the CGI lessons had the highest proportion of questions (48% and 52% of the teachers' utterances). Questions comprised smaller proportions of teacher's talk in the other lessons (38% and 36% of teacher's talk in the Saxon lessons and 25% and 21% of the teacher's talk in the SFA MathWings lessons). When asking questions, one CGI teacher and one SFA teacher asked near equal proportions of lower-order and higher-order questions. The other CGI and SFA teachers and both Saxon teachers asked proportionately more lower-order than higher-order questions.

These findings about question types and the nature of mathematical tasks suggest that American Indian students experience different levels of cognitive challenge when taught by teachers in schools that have adopted different approaches. Further research using an experimental design is warranted examining whether the higher cognitive challenge associated with adoption of CGI fosters American Indian student proficiency in mathematical problem solving and reasoning.

Findings regarding similarities and differences between lessons taught from the different approaches were mixed regarding the extent to which there was evidence of responsiveness to American Indian student's culture. Discrepancies between lesson ratings based on two different rubrics reflecting responsiveness to Native culture suggested clarification is needed. Clarification about the different constructs and dimensions of culturally responsive instruction is needed as well as more input from Native teachers and individuals on the substance and measurement of culturally responsive instruction. The present set of six videotaped lessons and transcripts provide a good source of data with which to carry out such a process of clarification and develop more valid and reliable instrumentation.

Results are preliminary but relevant to teachers and instructional leaders in schools serving American Indian students. The lesson case study approach allowed descriptive comparisons to be generated and considered based on empirical data. Mathematics reform emphasizes equity and excellence for all students; yet, much of the knowledge available about how to accomplish these goals is ideological or policy-based rather than empirical. The present study offers a descriptive analysis and comparison of six lessons taught to American Indian students. The descriptions provide a snapshot of practices that are often considered "best practices" for American Indian and other students. These best practices have evolved to provide opportunities to learn challenging academic standards. Although the present results raise more questions than they answer, the study gives readers a framework for systematically reflecting on classroom practices and asking if American Indian students are truly engaged in optimal learning.

Purposive sampling was used to identify a set of lesson cases with which to compare and contrast different, currently adopted approaches to mathematics. Criteria for school selection included, 25% or more American Indian students at the elementary level and an approach to mathematics from among a list of currently adopted approaches in schools serving American Indian students. Nominations for exemplary teachers in the adopted approach were sought from school principals and staff developers. In this manner, the sample included one classroom at each of grades 3 and 4 in which Saxon Math, Cognitively Guided Instruction (CGI), or Success for All MathWings (SFA) was adopted. The 4th grade CGI classroom was a combined 4/5 classroom. The six teachers were in four elementary schools serving communities on or near Indian reservations. Of these, three schools were local education agency schools and one school was a tribally operated Bureau of Indian Affairs school.

In the second half of the 2004–2005 school year, teachers identified a typical lesson using their approach. Each lesson was videotaped and transcribed. Data were also collected to assess student aptitude and achievement, teachers were surveyed and interviewed, state and community demographic and historical information was reviewed, and program descriptions provided on product websites and in the research literature were reviewed. Data analysis focused on the interactions and social dimensions of each lesson within the context of the particular group of students and approach. Rubrics and coding rules were developed and applied to the lesson videotapes and transcripts and inter-rater reliability was established. Teaching was analyzed with respect to standards of professional practice in mathematics as specified in the National Council of Mathematics Teachers professional standards (National Council of Mathematics Teachers, 1991). Student aptitude and achievement data were summarized with descriptive statistics for each class and the

American Indian subgroup. Convergence of patterns from multiple sources of data was assessed and a cross-case analysis conducted.

An important aspect of the study was the formation of the research partnership for studying the teaching of American Indian students from the predominant culture as well as American Indian cultures. In particular, the present findings by challenging previous notions of best practices highlight the need to sustain and expand partnership research on what works for improving American Indian student achievement.

INTRODUCTION

For American Indian students, federal and state policies emphasize educational opportunities that not only assist students in reaching challenging academic standards but also respect tribal traditions, languages and cultures (White House Executive Order: American Indian and Alaskan Native Education, 2004; Elementary and Secondary Education Act, Title VII, 1988; North Dakota Indian Education Curriculum Title 15.1-21-05). Educators working with American Indian students need information about whether different approaches to mathematics are likely to create both culturally respectful and academically challenging opportunities to learn.

To initiate a program of research that addresses this need, in 2003, McREL formed a research partnership consisting of researchers, regional teachers, and local and state education leaders. The purpose of the partnership was to conduct meaningful, methodologically sound research in mathematics education and, by doing so, provide a region-specific infrastructure and set of resources to practitioners for developing and weighing different possibilities for teaching mathematics to American Indian students. The current focus of the partnership work is in elementary school education.

REGIONAL CONTEXT

More than 245,000 American Indians live in communities across three north central states, Nebraska, North Dakota, and South Dakota (U.S. Census Bureau, 2005). In North Dakota and South Dakota, among 4th grade American Indian students, mathematics achievement, on the National Assessment of Academic Progress (NAEP), has shown steady improvement. As shown in Figure 1, the percentage of American Indian students in North Dakota performing at or above the Basic level increased from 38 percent in 2000, to 52 percent in 2003, to 66 percent in 2005 (U.S. Dept. of Education). Similar trends are apparent in South Dakota, where the percentage of American Indian students performing at or above the Basic level increased from 54 percent in 2003 to 62 percent in 2005. In North Dakota, white students' performance levels also increased, from 77 percent in 2000, to 87 percent in 2003, to 91 percent in 2005. White students' performance levels also increased from 87 percent in 2003 to 90 percent in 2005 in South Dakota. In 2003[1], 61 percent of American Indian students in Nebraska performed at or above the Basic level in mathematics. The percentage of white students in Nebraska who performed at or above the Basic level was 87 percent in 2003 and 88 percent in 2005.

Despite advances in achievement for American Indian students, gaps persist as white students have also advanced (see Figure 1). Researchers offer two explanations for the persistent gaps: (1) low expectations for learning and achievement (Chavers, 1999; 2000) and (2) a lack of culturally responsive curriculum and practice (Demmert & Towner, 2003;

[1] In Nebraska, NAEP data for 4th grade American Indian students are available only for the year 2003.

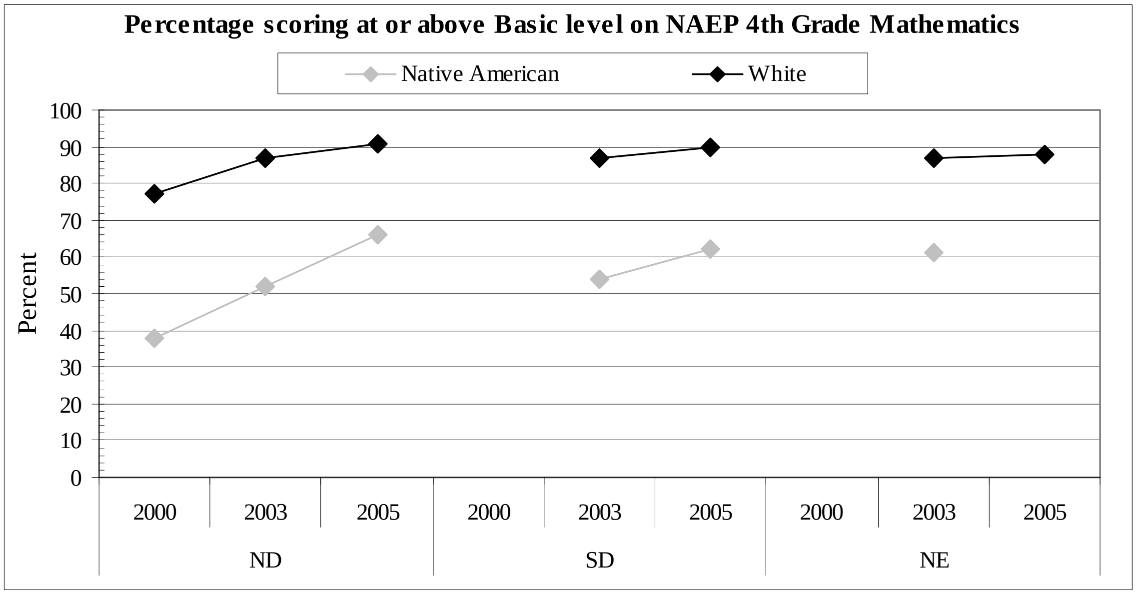

Figure 1. Fourth Grade Mathematics Achievement Gaps in North Dakota, South Dakota and Nebraska

Yamauchi & Tharp, 1995). In response, efforts to raise expectations have been initiated and more culturally responsive approaches to mathematics have been adopted in this region's schools.

The challenges posed by the low achievement of American Indian students are somewhat unique to the north central United States. In North Dakota, half of the 321 elementary schools, including both public and Bureau of Indian Affairs (BIA) schools, include American Indian students. In 80 of these schools, American Indian students comprise either the majority or a significant subgroup. The public school programs are generally not bilingual, and the student populations are culturally diverse where in addition to various American Indian heritages (e.g., Ojibwe, Sioux), students are of different Northern European ethnic and cultural heritages, often German, Norwegian, Irish and Russian. The North Dakota and South Dakota schools with the highest percentage of American Indian students often are located in isolated rural locales (e.g., a 4-hour drive from the state capital) and/or tend to be higher-poverty schools with an average free or reduced-price lunch (FRL) rate of 50 percent (ranging from zero to 98%), considerably higher than the state average FRL rate of 35 percent (Apthorp, 2004).

In this context, a variety of mathematics initiatives have been adopted to improve American Indian student achievement. Some schools have adopted approaches that claim scientifically-based evidence of effectiveness, including Saxon Math and Success for All MathWings. Other schools have adopted approaches based on constructivist theories of learning, including TERC Investigations and Everyday Math. And, others have adopted textbook series, including Houghton Mifflin or Scott Forseman-Addison Wesley. Additionally, district and state initiatives support teacher professional development as a way to reform mathematics education. Two such programs include Cognitively Guided

Instruction (CGI) and Developing Mathematical Ideas (DMI). Finally, teachers of American Indian students in North Dakota and South Dakota report using a National Council for Teachers of Mathematics (NCTM) guidebook (Hankes and Fast, 2002) as a source of ideas on how to ground mathematics lessons and activities in Native culture (Apthorp, 2004).

Rather than importing yet another initiative or disrupting the momentum toward improvements already established, McREL's line of research in this area focused on examining currently adopted approaches. In 2004, as McREL's regional research partnership set a direction, the purpose of the present study was identified to assess the potential impact of currently adopted approaches on teaching and student achievement.

STUDY PURPOSE

The purpose of this study is to examine implementation of the different approaches in classroom-specific contexts as defined by lessons taught to classes comprised of either a significant minority, or a majority of students with American Indian cultural heritage.

Members of McREL's regional research partnership expressed a desire to answer practical questions. Members sought answers to such questions as, "Which is better — a comprehensive curriculum and approach, such as Success for All MathWings, or professional development in mathematics for teachers, such as that offered by Cognitively Guided Instruction?" Additionally, partnership members clearly identified goals for American Indian students: self-confidence, self-motivation, ability to reason, and preparation that opened doors to multiple options in later grades and in adulthood (meeting notes, 2/28/04; Bismarck, North Dakota).

Acknowledging the variety of instructional and curriculum approaches currently adopted, the present study sought to explicate, by comparing and contrasting their implementation for American Indian students, the relevant variables and to develop instrumentation to measure them. Among the questions asked are: Do the different approaches create different opportunities to learn for students? How do teachers use the different approaches to engage and sustain student interest in mathematics? How do teachers use the different approaches to promote student mathematical reasoning? Are the content and skills specified in standards taught with the same or different methods? What outcomes are associated with use of the different approaches?

CONCEPTUAL FRAMEWORK

In this study, classroom instruction and learning are viewed as functions of the interaction between teachers, students, and content (Cohen & Ball, 2000). This view aligns with a priority area of focus in Indian education research identified by Swisher and Tippeconnic (1997), namely, teaching-learning relationships. Teaching-learning relationships comprise "the most basic interaction [between students and teachers] that takes place in schools each day and one that determines whether students will persist [in their academic work] or not … a mutually respectful and caring relationship is essential to educational success" (p. 302). Secondly, it was assumed that higher student performance would be associated with high-quality teaching, defined recently as: "integration of active, intentionally instructive behaviors with a socially warm and responsive interpersonal approach" (National Institute of Child Health and Human Development Early Child Care Research Network, 2005, p. 307). Therefore, the study focused primarily, but not exclusively, on the interactions and social dimensions of classroom instruction.

We examined the nature of the interactions and social dimensions of classroom instruction through two frameworks. One framework is the National Council of Teachers of Mathematics standards of professional practice (NCTM, 1991). These standards, representing major reforms in mathematics teaching, are organized around four areas of teacher's work, mathematical tasks, discourse, learning environment, and assessment. The standards of practice embody high expectations for student engagement in mathematical problem solving and reasoning, and emphasize conceptual understanding, making connections, and communication. These characteristics of practice reflect academically challenging opportunities to learn.

The second framework is a cultural compatibility framework. We summarize research on the unique aspects of American Indian culture in relation to learning, teaching, mathematics, and communication, and identify possible dimensions of culturally responsive teaching in classrooms for American Indian students. Thus, in addition to examining evidence of academically challenging opportunities to learn as evident in adherence with the NCTM (1991) standards of professional practice, this study examines evidence of culturally responsive instruction for American Indian students.

NCTM (1991) Standards of Professional Practice

Worthwhile tasks and productive discourse are core features of mathematics reform (NCTM, 1991). Neither one alone is sufficient to assist students in developing mathematical proficiency. The third and fourth areas of teaching addressed by the NCTM (1991) standards of practice, learning environment and assessment, are concerned with how to structure time, space, materials, and social support and norms, in general, and feedback for individuals, in particular, that support mathematical development.

Worthwhile Tasks

Worthwhile tasks establish the intellectual context for developing mathematical understanding, reasoning and proficiency. Worthwhile tasks embed abstract concepts in concrete terms making learning mathematical concepts and relationships easier (Mamona-Downs & Downs, 2002). In the National Research Council report, *Adding it Up*, tasks involving sharing equal amounts or "fair shares" are discussed as examples of creating opportunities for students to tap into and build on their informal understanding of and prior experience with rational numbers (Kilpatrick, Swafford, & Findell, 2001). To assist students develop proficiency with performing operations using rational numbers, "instruction should build on students' intuitive understanding of fractions and use objects or contexts that help students make sense of the operations" (p. 240). Moreover, having students work with a variety of different physical models in addition to pictures and real-world contexts, accompanied by verbal descriptions and more formal symbolic representations, helps students develop understanding of concepts and their mathematical terms.

Discourse

The NCTM (1991) professional standards of practice emphasize "time for reflection and analysis, for students to articulate their own approaches" (Russell & Corwin, 1993, p. 557). This is in direct contrast to approaches that emphasize "coverage" and "getting through" subject matter. For low-achieving students, in particular, research supports the efficacy of constructivist approaches that emphasize problem solving, exploration and listening to and questioning students (Knapp and Associates, 1995). Mathematics teachers who ask open-ended, cognitively challenging questions engage students in conversations about the tasks, prompting reflection and explanation (Chapin, O'Connor & Anderson, 2003). It is this reflection and explanation that allows teachers and students to recognize misconceptions, consider alternative meaning, and try-out and rehearse new understanding. In correlational research, more verbal interaction and cooperativeness, fostering clarification, persuasion, and exchanges of help-seeking and help-giving, are associated with higher achievement and more complex thinking (Bransford, Brown & Cocking, 2000 Ben-Ari, 1997; Fenneman, Carpenter, Franke, Levi, Jacobs & Empson, 1996).

Learning Environment and Assessment

Adoption of the NCTM (1991) standards of practice includes creating a learning environment that provides enough time to explore, reflect upon, justify, and discuss the mathematical ideas, relationships and solutions that emerge during the worthwhile tasks. Teacher attributes associated with these standards of practice (NCTM, 1991) include, for example, the following:

- Respecting and valuing students' ideas, ways of thinking, and mathematical dispositions
- Providing and structuring the time necessary to explore sound mathematics and grapple with significant ideas and problems
- Expecting and encouraging students to work independently or collaboratively to make sense of mathematics

Cultural Responsiveness

Culture is defined as "the set of ideas, beliefs, assumptions, and norms that are widely shared among a group of people and that serve to guide their behavior" (Tharp, Estrada, Dalton & Yamauchi, 2000, p. 107). Disregarding cultural differences in the context of teaching and learning "may create unintended mischief" and "preclude effective assistance and guidance" (Tharp et al., 2000, p. 108). Some argue that when teachers do not recognize how behavior is culturally influenced, they inadvertently "alienate and marginalize some students" (Weinstein, Curran, Tomlinson-Clarke, 2003). Alternatively, when diverse patterns of communication, values, thought, customs and actions are recognized and adaptations are made reflecting such diversity, there is more likelihood that students from non-mainstream groups can participate on their own terms instead of at another's discretion (King, Sims & Osher, 2005; Kivel, 2001).

Research suggests that caring adults (e.g., teachers who really listen to what students have to say), teacher-student mutual respect, and clear and high expectations promote effortful participation from many minority students (Allexsaht–Snider & Hart, 2001; Borman & Overman, 2004; Tharp, Estrada, Dalton & Yamuachi, 2000). From this perspective, when the cultural disposition of students and the school are congruent, class and school environments are more effective for learning (Demmert & Towner, 2003).

High Expectations

American Indian students often have experienced low expectations and misunderstanding from their teachers (Deyhle, 1992; Gilliland, 1999). American Indian students are more likely to be labeled "learning disabled" or "learning handicapped" than other minority students (Yamauchi & Tharp, 1998). Evidence suggests, however, that the scholastic problems are alleviated with high expectations. In exemplary schools for American Indian students, "expectations are extremely high" (Chavers, 1999, p. 8). Consistent with Chavers' observation, other research strongly suggests that high expectations and challenging standards are maximally influential in effective schools and classrooms (Brophy, 1986; Levine & Lezotte, 1990; Lumsden, 1996).

In exemplary schools for American Indian students, students are eager to learn; they study two to four hours every day; they do homework daily and if they have no homework, they read up to three or four books a week (Chavers, 1999). In mediocre programs, the curriculum is weak, watered down, out-of-date; it does not challenge students; little homework is assigned; reading is not required; typically, "mediocrity from both teachers and students" is acceptable (Chavers, 1999, p. 11).

High academic expectations and cognitive challenge are particularly important complements to and criteria for evaluating culturally responsive pedagogy. To avoid trivializing mathematics in culturally responsive pedagogy (Nelson-Barber & Estrin, 1995) and develop student understanding and more abstract mathematics, Davidson (1989) suggests use of systematic language activities, such as having students describe and explain their procedures and solutions, and create and solve story problems in writing.

Cognitive Challenge

Research supports the effectiveness of problem-based mathematics instruction and teaching that encourages students to describe and explain their procedures and solutions (Holm & Holm, 1995; Hilberg, Tharp & DeGeest, 2000; Lipka & Adams, 2004; Rosier & Farella, 1976). For American Indian students in the southwestern United States, an instructional emphasis on group work, real-world problem solving, and instructional conversations was associated with higher mathematics achievement than that for students taught using an explicit, direct instruction approach (Hilberg, Tharp & DeGeest (2000). Similarly, in an American Indian community school in Wisconsin, children taught by a teacher using a problem-based learning approach performed at or above proficient levels on mathematical problem-solving assessments (Hankes, 1998).

When teachers pose good questions, the questions are a "catalyst for students' thinking and talking" (Chapin, O'Connor & Anderson, 2003, p. 139). Cognitively challenging questions prompt active mental processing, including explanation, evaluation, analysis, and synthesizing. In contrast, questions that are not cognitively challenging ask students to recall, recite and identify information (Anderson et al., 2001). An overemphasis on cognitively challenging questions, however, is not likely to benefit American Indian students. There are times when direct instruction on how and when to use different problem solving strategies is beneficial and exposure to correct solutions and corrective feedback provides clarity for learners (Baker, Gersten & Lee, 2002; Kroesbergen, van Luit, & Maas, 2004,Ysseldyke, Spicussa, Kosciolek & Boys, 2003).

Emphasis on Cooperativeness & Helpfulness

In most American Indian groups, there is a collectivist orientation where personal issues are subordinate to the collective interests. According to Cajete (1999), "mutualism permeates everything in the traditional Indian social fabric" (p. 141). There is a sense of belonging and solidarity with group members cooperating to gain group security and consensus" (Cajete, 1999, p. 141). For children from some American Indian groups, public display of knowledge is not in keeping with community norms (Swisher and Deyhle, 1992), and therefore, cooperative work and conversations in diads and triads may be more culturally congruent than singling out students in front of a whole class. According to Tharp and Yamauchi (1994), other considerations for American Indian students are increased wait time, an emphasis on peer- and activity-based versus teacher-oriented discussions, slowed tempo of events and conversations, indirect eye gaze, and engagement when ready instead of by teacher command. Because "talking for talking's sake" is rare in Native communities, other considerations include nonverbal orientation, quietness, and humility (Cajete, 1999, p. 141).

Making Connections to Out-of-School Experiences

One of the potential mismatches between school and home for American Indian students is the difference between "formal" and "informal" teaching and learning (Yamauchi & Tharp, 1995). Learning in school is often out-of-context in contrast to informal learning which involves learning while carrying out "real-world" activities and responsibilities, for example, in the context of a family business of jewelry making and selling (Yamauchi & Tharp, 1995). Cajete (1999) suggests that American Indians tend to be practical and recommends that numerous concrete examples be used in teaching with approaches that are experiential and concrete rather than theoretical and abstract. When students are allowed to pursue topics of their own interest, generate their own interpretations and when their local surroundings are incorporated into the curriculum and classroom, American Indian students participate in classroom activities. The inclusion of real-world activities is likely to facilitate conversation in lessons (Yamauchi & Tharp, 1995).

Observational Learning Opportunities

While language is the predominant mode of teaching and learning in school, observational (modeling) learning is the predominant mode in out-of-school informal learning (Yamauchi & Tharp, 1995). Informal learning opportunities through observation are also situated in affective relationships. Cajete (1997) suggests that American Indian students often respond best to learning that is "group oriented and humanized through the extensive use of narration, humor, drama, and affective modeling in the presentation of content (p. 144).

According to some educators, Cognitively Guided Instruction, as a professional development program in teaching mathematics, enhances the cultural appropriateness of mathematics for Native American and other minority students (Hankes, 1998; Tharp et al., 2000). In CGI, for example, paired or group problem solving and solution sharing is emphasized and instruction is time-generous rather than time-driven. Also, the fact that CGI builds on children's accomplishments and complements rather than contradicts what children already know is congruent with Native American pedagogy. In contrast to the metaphor of teaching where students are viewed as "blank slates onto which information is etched," from the CGI and Native American perspective each student "is a born thinker," constructing and revising emerging theories about the world (Hankes & Fast, 2002, p. 44).

To summarize, there is a need to extend and refine research-based findings about teaching mathematics to American Indian students. Research is needed to help sort out which practices, or combination of practices, encourage the kinds of task participation and verbal interactions that are effective for improving American Indian student achievement in mathematics.

STUDY DESIGN

In view of the disparate and contradictory knowledge about how to effectively engage American Indian students in worthwhile mathematical tasks and discourse, research that is designed to identify and help clarify key variables is warranted. The purpose of this study is to more precisely understand key variables and processes in mathematics instruction for American Indian students that lead to higher achievement. In response to the informational needs of regional educators, this study compares and contrasts lessons taught from different approaches to mathematics in use today. Lessons are the unit of analysis, providing holistic contexts within which to examine opportunities for American Indian students to develop mathematical reasoning and proficiency through worthwhile tasks, cognitively challenging questions, and a culturally responsive learning environment.

The study uses a mixed methods comparative case study design, a design which is appropriate when information about a particular group or locale is not available or very limited (National Research Council, 2002). The study is part of an ongoing line of research on effective instruction for American Indian students. As preliminary conceptual/empirical work for later experimental inquiry, this study is intended to clarify key constructs and variables, examine relationships among variables, and recommend measures for independent, dependent and control variables regarding instruction for Native American students.

RESEARCH QUESTIONS

The primary questions addressed in this study are:

1. What are the differences among the lesson cases, across approaches and grades, in terms of the nature of the mathematical tasks, discourse, and learning environments? Specifically, are there differences in terms of:

    a. Emphasis of the mathematical tasks on problem solving, reasoning and making connections?

    b. Ratio of teachers' telling statements to questions?

    c. Level of cognitive demand in teachers questions?

    d. Sensitivity of the instructional interactions and classroom environment to American Indian culture and heritage?

e. Student mathematics achievement?

2. What patterns or relationships are likely to be fruitful foci for future experimental research designed to address the question of what works to improve Native American student mathematics achievement?

METHOD

McREL employed a comparative case study design that incorporated mixed methods, including videotaping of lessons taught from different approaches, quantitative analyses of statement/question ratios and level of cognitive demand in teacher-talk and questioning, and narrative case reports to tell how each approach was enacted in a typical mathematics lesson. An overview of data collection and analysis procedures is presented in Table 1. Purposive sampling was used to create a sample of lessons that embody the principles of a constructivist approach and a comparable sample of lessons that embody the principles of an explicit, direct instruction approach. Site visits involving interviews, observations, and videotaping were conducted in the second half of the 2004–2005 school year. Student assessments were administered at the end of the 2004–2005 year.

Table 1. Overview of Data Collection and Analysis

Focus	Data Source	Variable/Outcome	Analysis
Mathematical Tasks Mathematical Discourse Learning Environment	Lesson videotape Lesson transcript Reform Pedagogy Ratings Bloom's Cognitive Taxonomy Categorization Interview & Survey Sensitivity to American Indian cultural and heritage ratings	Statement/Question Ratio in Teacher's Talk Level of Cognitive Demand Precision Emphasis on problem solving and reasoning Cooperativeness Public/private voice	Identify and examine patterns and relationships between teaching and context variables within and across lesson cases and approaches
Student Aptitude and Achievement	Wide Range Test of Achievement (WRAT) Iowa Test of Basic Skills (ITBS)®	Nonverbal Reasoning Math Achievement	Descriptive statistics for whole class and American Indian subgroup. Compare achievement to norm-referenced median grade-level performance.

SAMPLE

A purposive sampling strategy was used to identify schools serving at least 25 percent American Indian students, in which either a constructivist or explicit instruction approach to mathematics could be observed. Three approaches were selected: Saxon Math, Cognitively Guided Instruction (CGI), and Success for All MathWings. Study participation agreements were established with school officials in four schools in two states, North Dakota and South Dakota. The American Indian students attending these particular schools are primarily descendants of people of the Dakota/Lakota Nation, also referred to as the Great Sioux Nation.

School Context

School 1, a tribally operated school located on a reservation, serves 5 towns that together have a total of 20,000 residents. Approximately 1,000 students, kindergarten through grade 12, attend the campus of School 1. Student enrollment is 100 percent American Indian.[2] The school adopted Saxon Math seven years prior to the study. Consistent with observed achievement characteristics of the state's white and Native American student populations (see Figure 1), School 1 has shown gains in Native American student achievement but remains approximately 14 percentage points behind white students scoring Proficient or Advanced on the state mathematics assessment.[3]

School 2, operated by a public school district, is located near a reservation belonging to a Sioux tribe with more than 5,000 members. School 2, kindergarten through grade 6, has an enrollment of 80 students, 64 percent of whom are American Indian. Eighty percent of students at School 2 are eligible for a free or reduced lunch rate.[4] Two years prior to the study, the school principal and primary grade teachers made a commitment to adopting Cognitively Guided Instruction (CGI) for teaching mathematics and have participated in CGI professional development ever since. Reported achievement data are not disaggregated for Native American students at this school. In the 2002-2003 academic year, 25 percent of 4th grade students performed at Proficient or Advanced, approximately 36 percentage points below the state average for 4th grade white students on the state mathematics assessment.[5]

School 3, also operated by a public school district, is located near another Sioux tribe reservation. The tribe has more than 24,000 enrolled members; 20,762 live on the reservation. School 3, pre-kindergarten through grade 5, has an enrollment of 308 students, of whom 99 percent are American Indian. Ninety-eight percent of the students are eligible for a free or reduced lunch rate.[6] The school has adopted TERC Investigations for mathematics. School results from the 2003-2004 grade 4 state assessment indicate a gap of about 23 percentage points between this school's performance and the state's American Indian population scoring Proficient or Advanced in mathematics.[7]

School 4, operated by a public school district, is located in the vicinity of School 2 and near the same reservation. The school enrolls 115 students in pre-k through grade 4; 29 percent are American Indian. A total of 65 percent of students were eligible for free or reduced lunch rates.[8] The school adopted Success for All Reading six years prior to the study and soon afterward adopted Success for All MathWings. The school staff includes a parent

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[1,3,5,7] Source: CCD Public school data 2003-2004 school year.
[3] Source: Bureau of Indian Affairs, Office of Indian Education Programs, Annual Report Cards 2002-2003, available from http://www.oiep.bia.edu/, and South Dakota Department of Education State Report Card, 2003, available from http://doe.sd.gov/.

[5] Source: North Dakota State Profile 2002-2003, and North Dakota School Plant Profile 2002-2003, available from http://www.dpi.state.nd.us/.

[7] Source: South Dakota Department of Education State Report Card, 2003-2005, available from http://doe.sd.gov/.

liaison who works specifically with American Indian students. At the district level, the Local Indian Education Board (LIEB) serves as an advisory board for the district's Johnson O'Malley (JOM) and Title IX Indian education program. This school does not disaggregate data for its Native American population of students, so direct comparison of group performance is not possible. However, this school outperformed the state's Native American population in Grade 4 state mathematics achievement the previous two years, and outperformed the state's white population in Grade 4 mathematics the previous year.[9]

Classroom Context

At each school, grade 3 and 4 teachers and their students participated in the study. These classrooms and teachers were identified by their principal or a staff developer as exemplary in use of the school's particular approach to mathematics. To examine the implementation of the different approaches, one lesson was videotaped in its entirety. Criteria were established to identify the lesson, including identification by the teacher as typical for the approach adopted, and that the lesson was conducted in the second half of the 2004–2005 school year after routines and the nature of the learning environment had been established. Characteristics of classroom contexts for each of the 6 lesson cases are summarized in Table 2 and presented within each school.

Table 2. Composition of the Study Classrooms by Lesson Identification

School	Approach	Grade	Lesson Identification	Number of students in Classroom	Percentage American Indian
1	Saxon Math	3	**Saxon-3**	18	100%
		4	**Saxon-4**	24	100%
2	Cognitively Guided Instruction (CGI)	3	**CGI-3**	14	50%
3	Cognitively Guided Instruction (CGI) supplementing TERC Investigations	4/5	**CGI-4/5**	22	95%
4	Success for All MathWings	3	**SFA-3**	19	47%
		4	**SFA-4**	18	28%

Data Collection Procedures

Videotaping and Lesson Transcription

After gaining permission to videotape lessons, visits to each study classroom were arranged during the second half of the 2004-2005 academic year. One 45 to 75 minute lesson was videotaped in each study classroom. The videographer[10] filmed each lesson from the back of the classroom. The teacher wore a wireless lavelier microphone. For each lesson, the

[9] Source: North Dakota State Profile 2002-2003 and 2003-2004, and North Dakota School Plant Profile 2002-2003 and 2003-2004, available from http://www.dpi.state.nd.us/.
[10] Mr. RunningHorse Livingston, Lake Superior Band of Bad River Chippewa, videotaped each lesson as part of a minority internship position at McREL.

videographer primarily recorded the teacher's behavior and instructional conversations. In addition, the videographer scanned the whole classroom and included close-up shots of student work in each lesson. The videographer produced each lesson tape in a DVD format, editing to smooth transitions and adjust lighting.

McREL transcribed the videotaped lessons verbatim in preparation for analysis of the teacher's instructional conversation. A second researcher verified the accuracy and completeness of each transcript against the video. Time stamps were used at frequent intervals to reference occurrences during the lesson.

Teacher Survey and Interview

Participating teachers were asked to complete two surveys. The first one, a two-page survey, asked about the teachers' teaching experience, preparation and licensure and the composition of their class. The second survey, collected after the lesson took place, asked the teacher for specific reflections on the videotaped math lesson. In addition to the surveys, the videographer conducted a structured interview with each teacher after the videotaping took place. The interview asked teachers if the lesson was a good example of the mathematics approach adopted in their school and why or why not. Teachers were also asked to describe lesson routines, how problem solving strategies are taught, and how students are encouraged to share problem solutions in the curriculum or approach. Teachers were asked to estimate the percent of time devoted to different types of activities (i.e., teacher explanation and assignment overview, group discussion, independent student work, and group work) and identify what they liked least and most about the curriculum or approach. Additionally, teachers were asked how they made lesson planning decisions and to describe their most able and least able students.

Student Assessments

To provide a common measure of student mathematics knowledge and skill across the lesson cases, the Iowa Test of Basic Skills® (Level 9 for 3rd graders and Level 10 for 4th graders) was selected. The content of the ITBS® mathematics subtests aligns with several of the outcomes identified by the research partnership as important, namely, ability to reason mathematically and demonstrate preparedness for advanced education and multiple options in adulthood. The subtest content is summarized as follows

ITBS® Math Concepts and Estimation

- Assesses understanding of math ideas, relationships, and visual representations. Students are asked questions about number properties, algebra, geometry, probability and statistics. Mental arithmetic and estimation skills are also assessed. Students have 30 minutes of working time.

ITBS® Math Problem Solving and Data Interpretation

- Asks students to solve word problems using stories, graphs and tables. Other questions ask students to use data displays to compare quantities and figure out trends or relationships. Students have 30 minutes of working time.

ITBS® Math Computation

- Requires use of operations (addition, subtraction, multiplication and division) with whole numbers, fractions, decimals and combinations of these. Students have 15 minutes of working time.

The ITBS® measures have adequate reliability and validity evidence for the purposes of the study and provide norm-referenced scores based on samples that represent populations of students in third and fourth grade classrooms in both urban and rural locales across all regions of the U.S. The ITBS® developmental standard scores (SS) represent a student's location on a developmental continuum of achievement expected with increasing grade levels of instruction. These scores are interpreted by using median SS values associated with each grade level; for example, the median SS for 4^{th} graders is 200. In this study, student performance is examined in relation to grade level expectations as indicated by the median SS for 3^{rd} and 4^{th} graders.

Also, a measure of nonverbal reasoning was selected for use as a way to compare aptitude of students across the lesson cases. This provides additional information on the cognitive context of the classrooms in which each lesson tape was produced. For this purpose, the Nonverbal Reasoning subtest of the Wide Range Achievement Test–Group (WRAT-G) (2001) was selected.

The WRAT-G Nonverbal Reasoning subtest assesses abstract reasoning in a manner not dependent upon reading ability. Students view five figures and must deduce a rule common to four of the five items and identify which element does not belong. The task is intended as a measure of general fluid reasoning ability. Internal consistency and test-retest reliability is adequate, with all coefficients equal to or greater than .80 (Robertson, 2001). Validity studies suggest that the WRAT-G Nonverbal Reasoning test measures what it intends to measure, with statistically significant correlation coefficients equal to or greater than .60 when correlated with the Otis-Lennon School Ability Test (O-LSAT) and Wide Range Intelligence Test (WRIT) (Robertson, 2001).

The WRAT-G Nonverbal Reasoning norm-referenced scores are based on samples that represent populations of students in third and fourth grade classrooms in both urban and rural locales across all regions of the U.S. The WRAT-G standard scores have a mean of 100 and standard deviation of 15.

Study teachers administered the WRAT-G and ITBS® subtests in late April or May 2005 according to standard procedures as specified in the Administration Manuals on three separate days beginning with the WRAT-G Nonverbal Reasoning test. Teachers were asked to administer the ITBS® with a proctor, such as the building principal or test coordinator. Teachers recorded whether or not individual students were American Indian or non-American Indian on the student answer sheets, assigned student numbers as directed, and returned completed answer sheets to McREL for scoring.

Data Analysis

Data were prepared and analyzed with rubrics and other measures developed to reflect NCTM (1991) principles of professional practice, levels of cognitive challenge and cultural responsiveness in the lesson, and grade level norms of mathematics achievement.

NCTM (1991) Principles of Professional Practice

McREL developed a rubric to rate each lesson according to the reforms described in the professional standards for teaching mathematics proposed by the National Council of Teachers of Mathematics (NCTM, 1991). The rubric incorporated the six NCTM (1991) professional standards: (1) worthwhile mathematical tasks, (2) teacher's role in discourse, (3) student's role in discourse, (4) tools for enhancing discourse, and (5) learning environment, and (6) analysis of teaching and learning. Sixteen items of practice, each with a 4-point rating scale, were included. In general, each item asked, "To what degree does the lesson reflect ...." and rated each item in a scale of 1 to 4 where 1 = not at all and 4 = extensively. Items assessed one of the four areas as follows:

1. worthwhile tasks that emphasized problem solving, reasoning and making connections,

2. discourse that encouraged students to reflect on and discuss their own and other's thinking, and to develop and extend their conceptual understanding to adopt the formal language of mathematics,

3. a learning environment that encouraged students to work together to make sense of mathematics, and

4. assessment and consideration of individual student understanding and differences.

At least two researchers viewed the lesson videotapes and applied the NCTM-based rating to each lesson holistically, considering each lesson in its entirety for each of the sixteen items. After viewing and rating two lessons, researchers compared scores, discussed discrepancies, and clarified the scoring process before applying the rating instrument to the remaining four lesson tapes.

Verbal Instructions and Interactions

The extent to which teachers' verbal instructions and interactions encouraged students to reason, think mathematically, justify and reflect on their problem solutions, and develop conceptual understanding was examined. To examine teacher's talk, McREL developed procedures for preparing lesson transcripts in which the unit of analysis was identified in a standard manner. The unit of analysis was an utterance, defined as a statement or question and bracketed by pauses in the teacher's speech or shift in meaning. Therefore, each turn a teacher took in communication with the class, a particular group, or a particular student was divided into utterances. Restatements to repair an error or restate a previous statement were not counted.

Each teacher utterance was classified as either a declarative statement or a question, regardless of content (e.g., mathematics, lesson management or behavior management).

Declarative statements, telling students a fact or how to do something, were defined as explicit explanations, procedural directions or prompts, definitions, restatements of student responses, or evaluative statements. Teacher questions were defined as inquiries to which students were expected to respond. Thus, the sentence, "We were talking about equivalent fractions, and what does equivalent mean?" consists of one declarative statement and one question.

Bloom's Taxonomy of the Cognitive Domain was used to classify questions. Bloom's taxonomy distinguishes between lower-to-higher levels of cognition involved in information processing and knowing. The lowest-level, Knowledge, is "a starting point" involving identifying, recalling, labeling and retelling. The next higher level, Comprehension, is "the basic level of understanding." Each higher level involves increasing interpretation and mental activity that draws on other knowledge, experiences, purposes and understandings. We used a rubric adopted from the Medical College of Georgia to define and distinguish the six cognitive levels in Bloom's taxonomy: (1) Knowledge, (2) Comprehension, (3) Application, (4) Analysis, (5) Synthesis, and (6) Evaluation.

During preliminary analysis of four lesson transcripts (Saxon-3 and -4 and CGI-3 and CGI-4/5), team members did not initially reach consensus on classifications. To resolve discrepancies, two members of the research team were selected to discuss ratings and reach consensus. These two raters jointly reviewed the preliminary classifications made on the first four transcripts and developed guidelines for resolving disputed categorizations; for example, teacher directives that were couched as questions were coded as 'telling' statements (e.g. "Write your answer in a complete sentence, okay?" SFA-4, 11:44). Moreover, many discrepancies were resolved by considering the utterance in the context of the lesson rather than by the interpretive punctuation of the written transcript. The raters became more skilled in the application of the rubric and coding of utterances as the analysis progressed, decreasing the occurrence of discrepancies. In an attempt to keep the analyses consistent, these two raters jointly analyzed the remaining two lesson transcripts (SFA-3 and -4). The final coded transcripts identified the number and percent of utterances classified as telling statements and classified within each level of questioning described in Bloom's taxonomy.

Cultural Responsiveness

A rubric was developed for systematically viewing, describing and comparing lessons in terms of each lesson's responsiveness to Native students' culture values, patterns and beliefs. The seven-item rubric identifies aspects of culture which, when acknowledged and respected, may prevent misunderstanding and offense, and promote perceptions of acceptance and feelings of belonging. The seven aspects of culture were selected based on a review of literature about culturally congruent teaching for Native students and consultation with Indian educators who are knowledgeable about Native culture. The seven aspects of culture are as follows:

1. **Privatization —** An interaction style that is personal, one-on-one, characterized by a soft voice, and likely to be common among families and communities with a Native American cultural orientation. When adopting this interaction style, teachers move within close proximity to individual students to talk and interact rather than, for example, addressing a student in a loud voice from across the room (Erickson & Mohatt, 1982).

2. **Child-led performance** (valuing humility) — A de-emphasis on stardom, adopting a protocol of politeness, and the expectation that the time for demonstrating mastery will be determined by students themselves; children perform when ready rather than by teacher-command (LaFrance & Nichols, 2004; Tharp et al., 2000).

3. **Child-sensitive pacing** — The extent to which children have the time to think about and formulate responses and time to complete activities (Hankes & Fast, 2002).

4. **Attention to the importance of family relationships** — Recognition of the potential importance for Native students of the (a) interdependency among family members, (b) possibly heightened role of grandmother as mother, and (c) support of a large extended family (John, 1988).

5. **Cooperativeness** — Valuing contributions to the group. Learning and tasks, and school work is done in groups and with partners (Cajete, 1999, Hankes & Fst, 2002; LaFrance & Nichols, 2004; Swisher & Deyhle, 1992).

6. **Connections with everyday life outside of school, with students' norms of experience** — The extent to which the lesson content, classroom environment and discourse connect to students' life experiences outside of school (e.g., working on cars with socket wrenches, which are measured in fraction sizes, connects to lessons on fraction concepts and procedures) (Cajete, 1999; Hankes & Fast, 2002; McREL Partnership meeting, February 28, 2004; Yamauchi & Tharp, 1995).

7. **Opportunity to learn through observing modeling** — This aspect of culture in a culturally responsive lesson encourages holistic, hands-on learning and includes role models in the students' community in the learning process (American Indian Science & Engineering Society, 1995; Cajete, 1999).

Each of the seven aspects of Native culture serves as an item with anchor descriptions and examples defining points on a 5-point scale. External review of this rubric by a Native individual indicated that the "frames of "family importance" and "life outside of school" were good, promising to be a rich research topic that has significant potential for educational policy."[11] Need for clarity was identified for #4, and concrete examples were added in response to this comment.

Raters, in this case, non-Native members of the research team and independent of the team members who applied the NCTM (1991) rubric, viewed the entire lesson videotape with the transcript on-hand and recorded evidence observed or heard in the lesson that matched the anchors. Next, raters scored each item based on the evidence recorded. The 5-point scale represents the extent to which an item is characteristic or typical of the lesson; thus, rather than reflecting frequency of occurrences or evidence, scores represent the extent to which the item characterizes the lesson. An 8th item provides an overall rating of the lesson's cultural responsiveness, independent of simply summing or averaging the seven item scores.

[11] Review completed by Dr. Donna Deyhle, 10-2-05.

Student Assessment

The McREL research team prepared descriptive summaries of student nonverbal reasoning scores (WRAT-G) and end-of-year mathematics achievement (ITBS®) for each study classroom. Additionally, class and student subgroup (Native and non-Native) average ITBS® developmental standard scores (SS) were compared to the median grade level scores provided by the test publisher. Median SS for spring of grade 3 and 4 are 185 and 200, respectively (Hoover, Dunbar, Frisbie, Oberley, Bray, Naylor, Lewis, Ordman & Qualls, 2003).

Triangulation and Cross-Case Analysis

Data from multiple sources were analyzed separately and then compared for triangulation and to bring important discrepancies to light. Because our sample includes two grade levels within each approach, it was possible to examine differences from two perspectives: across grade levels within approach and across approaches within grade level. For example, as illustrated in Figures 2 and 3, we compared and contrasted grade 3 classroom lessons across the three different approaches and compared and contrasted the two Saxon Math lessons at grades 3 and 4.

	Saxon	CGI	SFA
Grade 3	⇩	⇩	⇩
Grade 4			

Figure 2. Analyses across grade levels within approach.

	Saxon	CGI	SFA
Grade 3			
Grade 4			

Figure 3. Analyses across approaches within grade level.

RESULTS

Consistent with the research design and research questions, data from multiple sources were analyzed separately and then examined holistically. As Patton (2002) points out, through such an approach, each analysis yields informative results which are then combined to "elucidate complementary aspects of the same phenomenon" (p. 558). In this section, descriptions of the adopted approaches and each particular lesson context are provided first. Cross-case analyses follow that address the nature of the lesson in terms of adherence to the NCTM (1991) principles of professional practice, level of cognitive challenge evident in teachers' verbal instructions and interactions, and responsiveness to Native culture. Next, student achievement results are summarized. The results section concludes with identification and explanation of patterns and relationships between student achievement and classroom factors.

INSTRUCTIONAL APPROACHES

Reviews of program descriptions and research were conducted to provide a descriptive summary of each of the three approaches adopted in the study schools: Saxon Math, Cognitively Guided Instruction (CGI), and Success for All (SFA) MathWings. Briefly, the Saxon approach to mathematics involves three main elements, incremental instruction, continual practice and review, and frequent and cumulative assessments. Saxon Math is based on the view that insights develop through frequent exposure and repeated experiences. Cognitively Guided Instruction is not a curriculum, but a group of concepts about how knowledge of mathematics develops. The purpose of CGI is to expose teachers to research on how children think and develop mathematically and allow teachers to explore how they might use the knowledge in practice (Cwikla, 2004). From a CGI perspective, teachers act as facilitators or guides and pedagogy centers around children's own knowledge and developing understanding. According to SFA MathWings descriptions, MathWings is based on the NCTM (1991) principles of professional practice and on the principles of cooperative learning. SFA MathWings provides teachers who adopt constructivist views of learning with structured materials, assessments, teacher's guides and professional development. Further details about each approach are provided in Appendix D.

In this section, the three approaches are compared in relation to five learning and teaching qualities identified in the research literature as effecting American Indian student success. The five qualities are (1) high expectations, (2) cognitive challenge, (3) emphasis on cooperativeness and helpfulness, (4) making connections to out-of-school experiences, and (5) learning through observation. Theoretically, it might be expected that the approach with the greatest congruence between its characteristics and the qualities of teaching and learning considered to be influential to the success of American Indian students would be the approach most likely to positively impact learning and achievement.

The comparative analysis, as summarized in Table 3, suggests that all three approaches support high expectations for student learning. However, in both CGI and SFA MathWings, students are expected to take a more active role in the process. In both CGI and SFA MathWings the cognitive challenge is high; students develop solutions and explain and defend solutions. In terms of emphasis on cooperativeness and helpfulness, the three approaches differ from each other. In Saxon, the emphasis is placed on individual student learning. In CGI, the idea is that students help each other by watching and listening to each other. In SFA, cooperative learning is a major feature and interdependency among work groups, or teams, is emphasized.

Table 3. Comparative Analysis of Mathematics Approaches in Terms of Learning and Teaching Qualities Considered Influential to American Indian Student Success

Influential Qualities	Approach: Saxon	Cognitively Guided Instruction	Success for All MathWings
High expectations	Students are expected to learn the skills and concepts necessary for success in both everyday mathematics and in the quantitative disciplines.	Students are expected to build upon the natural mathematical understanding they already have.	Students are expected to focus on mathematical reasoning, developing concepts, prediction and estimation skills, exploring advanced problem-solving situations, explaining and defending their reasoning and gaining fluency in algorithm use.
Cognitive challenge	Mathematics is not difficult, just different. With time and experiences, students learn and familiarize themselves with skills and concepts. Complex concepts are broken into smaller, related increments that are easier to learn.	Cognitive challenge is *high.* Children decide how to best resolve problem situations and share their thinking. Teachers pose contra-arguments to students to challenge their thinking.	Cognitive challenge is *high.* Students solve mathematical problems, write explanations of their solution processes and explain and defend their mathematical reasoning before their classmates and teacher.
Emphasis on cooperative-ness and helpfulness	This approach does not emphasize group work for learning. Emphasis is given to structured, explicit instruction, and the teacher is the imparter of the instruction. The emphasis is placed on individual student learning.	Students help each other develop mathematical thinking by watching and listening to each other solve problems and explain their thinking.	Cooperative learning is a major feature of SFA. Students work individually, in pairs, and in teams. Students are given problems that they explore and solve as a team. The team's work is not complete until all members have learned the material being studied creating positive interdependence among team members.
Making connections to out-of-school experiences	Mathematics is viewed as a foundation for the challenges of everyday life. It is integral to everyday life.	Emphasis is on selecting individually and developmentally appropriate problems.	Students are presented with real-world mathematical problems; teacher and students interact to explore concepts and practical applications. Connections with literature and other content areas is encouraged.
Learning through observation	Saxon publishers believe that students learn by doing and	Modeling problems and problem solutions are natural ways to learn mathematics.	Manipulatives are used first to help students develop solutions. Demonstrations and discovery are used to formalize and

Influential Qualities	Approach		
	Saxon	Cognitively Guided Instruction	Success for All MathWings
	practicing the problems themselves.		expand math knowledge and to move from concrete to symbolic representations.

The approaches also vary in terms of the extent to which making connections between school and home is an explicit component of the approach. In SFA MathWings, students are presented with real-world mathematical problems. Saxon's conception of mathematics is that mathematics is integral to everyday life. Selecting individually and developmentally appropriate problems is a core teaching competency in CGI.

In terms of opportunities for observational learning, all three approaches provide such opportunities, but in different ways. In Saxon, the design logic is that learning evolves through practice, by having students do problems themselves. In CGI, modeling is conceived of and used as a natural and influential way to develop mathematics. In SFA MathWings, demonstrations and discovery, with and without manipulatives, are two of several strategies (including, for example, reflection and cooperative learning) used to formalize and expand math knowledge.

LESSON CONTEXTS

To examine how the three approaches are implemented, we compared math lessons taught using each of the approaches. The lessons targeted third and fourth grade classrooms (and one combined grade 4/5 classroom) in schools with 25 percent or more American Indian students. The study schools were located in rural or small towns: one located on a reservation and four located near reservations.

Saxon Lessons

Of the six teachers who produced the six lesson cases, two were American Indian. These teachers taught at a school on a reservation and had classes consisting of 100 percent American Indian students. Saxon Math had been the adopted approach to mathematics in the school for about seven years. Teachers reported that attendance was good with a few students with high absentee rates.

The third grade Saxon lesson (Saxon-3) took place in a classroom with 18 students, 9 boys and 9 girls. Information on participation in special education services not available. The teacher described the classroom/school as a safe place to be and his/her role as a dependable adult in student's lives. The teacher's interview often described the social dimensions of the classroom, for example, "Some of the girls like to go around and help, and that's ok with me, sometimes they explain it better than I do, trying to help them achieve the answer, don't just tell them the answer" (Saxon-3 interview).

The fourth grade Saxon lesson (Saxon-4) took place in a classroom with 24 students, 11 boys and 13 girls. Six students received special education services. This teacher's interview responses focused on the Saxon curriculum. At the time of the study, the teacher used a new version of the Saxon textbook, a combined 4/5 one that is a little more difficult for some of the students. The teacher observed that "the majority of students seem to be going along really good with it because if they're not getting a concept in one lesson, they review it in the next lesson and then the next and then the next." The teacher remarked, "I think if they push this version and get everybody using it all the time I think it'll be good." (Saxon-4 interview).

The Saxon-3 lesson content addressed fractions, whole numbers, graphing, timed facts, and linear measurement. The Saxon-4 lesson content addressed the associative property, lines and segments, and equalities and inequalities. Both teachers reported that their videotaped lessons were good examples of Saxon (Saxon-3: "because of the focus on more than one concept and different skill;" Saxon-4: "because it was right from the book."). Both teachers acknowledged that students work independently a lot and that group discussion is not allowed too often.

Cognitively Guided Instruction Lessons

There were seven boys and three girls in the CGI-3 classroom: seven American Indian students, both boys and girls, three of whom who were identified as special education students. The teacher reported that most students attend class regularly.

The third grade CGI (CGI-3) teacher was in the third year of using CGI and judged the videotaped lesson to be an excellent example of CGI because of its emphasis on problem solving, mathematical thinking, and use of different problem types depending on individual student development and understanding. Lesson content addressed fractions, place value, problem solving and mathematical justifications. Although TERC Investigations was recently adopted at this school, the particular videotaped CGI-3 lesson was not used in conjunction with TERC Investigations. The teacher explained that the lesson was planned based on prior experience with CGI and current events at school. The teacher further explained using teachable moments in the lesson "to extend student knowledge of symmetry and shapes which in addition to fractions and understanding parts are also part of the state 3rd grade standards and benchmarks" (CGI-3 Survey).

The CGI 4/5 teacher in another school had used CGI for 10 years and was actively recruited by staff developers to become a CGI trainer. Of the 22 students in the CGI-4/5 classroom, all but one was American Indian. Among the 20 students with demographic information available, there were 11 boys and nine girls; three of the American Indian students were identified as special education students. Most students attended class more than 90 percent of the time; a few have high absentee rates.

The CGI-4/5 videotaped lesson was judged to exemplify CGI for its emphasis on actively involving students in mathematical thinking and problem solving. In the lesson, CGI was used to supplement a TERC Investigations lesson on volume and capacity and units of measurement. The teacher explained that one intention was "to move students from the simple ideas of looking at shape to the more abstract notions of those shapes taking up space" (CGI-4/5 Survey). The teacher further explained, "I have never had a text book in my classroom so I have been "inventing" curriculum based on constant assessment of what works. I have been told that I independently stumbled upon CGI but I also borrow a lot from Investigations .... so I can't really pin myself to one approach over the other. They function in concert" (CGI-4/5 Survey).

Success For All MathWings Lessons

The SFA-3 and SFA-4 lessons took place in the same school. Most students attend regularly with a few students having high absentee rates. The school was in its 5th year of adopting SFA MathWings. The SFA-3 lesson took place in a classroom with 19 students of which 8 were American Indian; four students received special education services (3 white students and 1 American Indian student). The SFA-4 lesson took place in a classroom with 18 students, 9 boys and 9 girls, of which five were American Indian students. One white student received special education services.

The SFA-3 lesson content addressed comparing fractions and finding fractions that were greater than and less than a given fraction. SFA-4 lesson content addressed equivalence of fractions though multiplication and division which was related to expressing fractions in their simplest form. Both the SFA-3 and SFA-4 teacher judged their respective videotaped lessons as good examples of SFA MathWings. The SFA-3 teacher explained that the lesson exemplified the "very structured" nature of the program. The SFA-4 teacher explained that the lesson was planned based on the SFA teacher's guide and lesson plan books and according to the content determined in the program, explaining, content in "my year is all mapped out" (Saxon-4 Survey).

Adherence to NCTM (1991) Standards of Professional Practice

Results of the lesson rating with respect to adherence to NCTM (1991) standards of professional practice are organized and presented in detail in Table C-1 in Appendix C for each of four scales corresponding to four professional standards as follows. Averages of these ratings (based on a scale of 1 = "not at all reflective of the standard" to 4 = "extensively reflective of the standard") are presented in Table 4 below:

Standard 1: worthwhile mathematical tasks;

Standard 2: use of discourse;

Standard 3: learning environment; and

Standard 4: analysis of teaching and learning.

Ratings were examined across grade levels within each instructional approach. It was expected that the ratings in the use of reform pedagogy would reflect different practices associated with the three different approaches to teaching mathematics. Generally, examination of the average ratings per scale showed consistency within approach. As can be seen in Table 4, within grade level, for each category of professional practice, the CGI lesson was rated highest, followed by moderate ratings for the SFA lesson, and low ratings for the Saxon lesson (see also Figure 4). This pattern is consistent with the program descriptions provided as context for each lesson case and reported at the beginning of the Results section of this report. As an instrument, the NCTM reform pedagogy rubric offers promise for use in follow-up studies of the three approaches. The rubric clearly distinguishes pedagogy used in lessons that were taught within the contexts of different adopted approaches and ought to be useful in documenting mediators to student achievement.

Table 4. Average ratings of each lesson according to the NCTM's standards of professional practice ordered from lowest to highest ratings within grade level.

	Average Ratings Per Lesson		
	Grade 3		
	Saxon-3	SFA-3	CGI-3
Average Standard #1	0.80	1.40	3.80
Average Standards #2, 3 & 4	0.94	2.13	3.38
Average Standard #5	1.63	2.63	2.88
Average Standard #6	1.50	1.75	3.75
	Grade 4		
	Saxon-4	SFA-4	CGI-4/5
Average Standard #1	0.95	1.75	3.85
Average Standards #2, 3 & 4	0.88	2.56	4.00
Average Standard #5	1.31	2.63	4.00
Average Standard #6	1.42	2.50	4.00

VERBAL INSTRUCTIONS AND INTERACTIONS

Teacher's verbal communication was first examined across grade levels within approach. The proportion of telling statements and questions is presented in Table 5. Given the different contexts described above, we expected corresponding differences in lesson pedagogy. Because Saxon Math is self-characterized by explicit instruction, we expected Saxon teachers' talk to be characterized by a preponderance of explicit statements. The results of our examination of statement/question ratios were consistent with this expectation.

Table 5. Average proportions of teacher utterances

Type of Utterance (%)	Saxon-3[12]	Saxon-4[13]	CGI-3[14]	CGI-4/5[15]	SFA-3[16]	SFA-4[17]
Teacher telling statements	62%	64%	52%	48%	75%	78%
Knowledge questions	27%	23%	26%	25%	12%	13%
All higher-order questions**	11%	13%	22%	27%	13%	8%

** "Higher order questions are those classified in Bloom's Taxonomy as Comprehension, Application, Analysis, Synthesis, and Evaluation.

[12] Total count of utterances: 362; Length of lesson: approximately 46 minutes
[13] Total count of utterances: 677; Length of lesson: approximately 59 minutes
[14] Total count of utterances: 785; Length of lesson: approximately 62 minutes
[15] Total count of utterances: 559; Length of lesson: approximately 48 minutes
[16] Total count of utterances: 722; Length of lesson: approximately 67 minutes
[17] Total count of utterances: 1283; Length of lesson: approximately 72 minutes

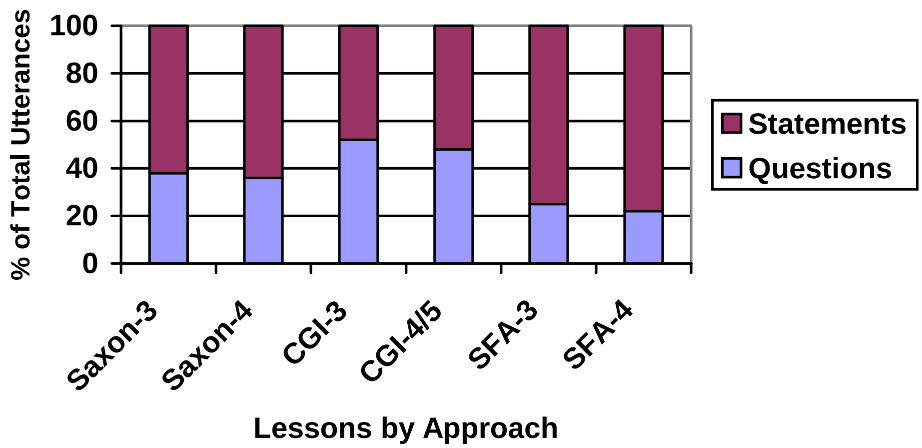

Figure 4. Statement/Question Ratios in Teacher's Talk Displayed by Approach

As can be seen in Figure 4, the statement/question ratio was about 60/40 for the two Saxon lessons, closer to 50/50 for the CGI lessons, and about 80/20 for the SFA lessons. The consistency within each approach-pair displayed in Figure 4 is in direct contrast to the differences within each grade-level-triad shown in Figure 5. This finding points to the possibility of a strong relationship between approach and the nature of teacher's talk.

Figure 5. Statement/Question Ratios in Teacher's Talk Displayed by Grade

Cognitive Challenge of Teacher Questions

Researchers applied Bloom's Taxonomy of the Cognitive Domain to teacher utterances identified as 'questions.' To review, Bloom's Taxonomy distinguishes between lower-to-higher levels of cognition involved in information processing and knowing. The lowest-level is Knowledge, followed by Comprehension, Application, Analysis, Synthesis, and Evaluation.

Figure 6 shows that, when teachers ask d questions, the questions were predominantly knowledge questions, asking for facts (e.g., "How many coins do I have?"). However, as also

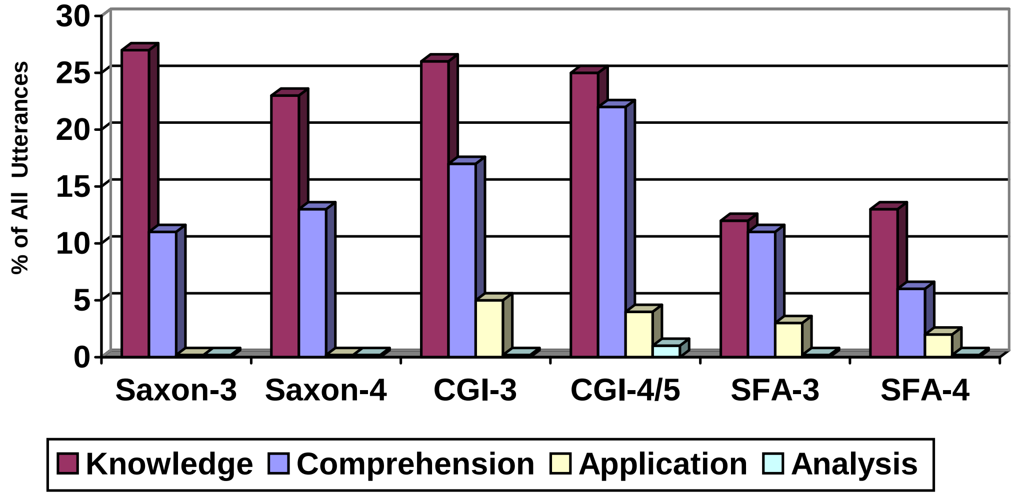

Figure 6. Distribution of Question Types in Teacher's Talk

seen in Figure 6, teacher's talk in the SFA-3 lesson showed near equal distributions of knowledge and comprehension questions. For example, the SFA-3 teacher asked, "Would you rather have ½ of a nine-inch pie or ¼ of a nine-inch pie? And why?" (20:41), prompting comparison, judgment, and explanation of the concepts one-half and one-quarter.

Cultural Responsiveness

Results of applying the cultural responsiveness rubric to each lesson tape revealed that on a 5-point scale for overall cultural responsiveness, one CGI lesson was rated high (CGI-4/5) and one was rated low (CGI-3). Both SFA MathWings lessons were rated high and both Saxon Math lessons were rated low. These scores are presented graphically in Figure 7.

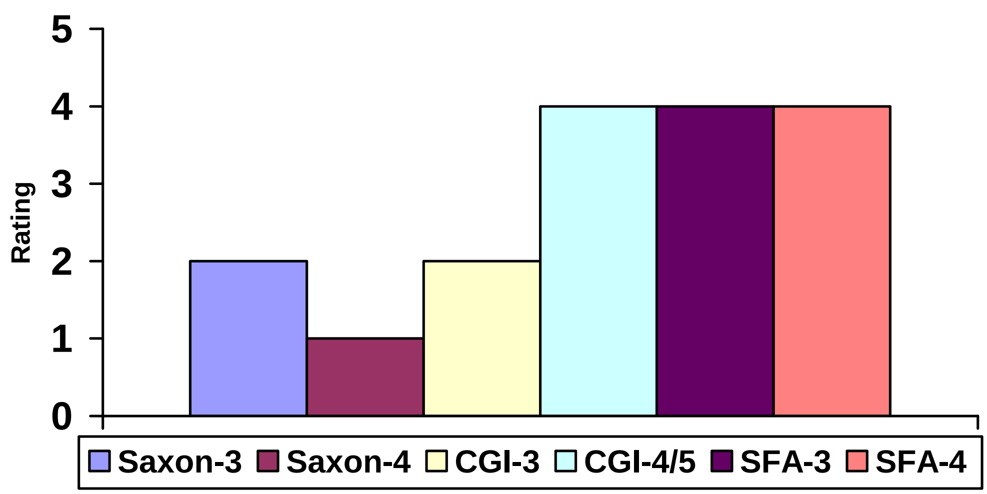

Figure 7. Overall Cultural Responsiveness.

Cooperativeness and child-led pacing most clearly distinguished the high and low lessons in terms of cultural responsiveness. In the SFA lessons, rated high in cooperativeness (See Figure 8) students sat and worked in teams and frequently discussed in teams or pairs. In CGI-4/5, students worked in teams to produce and test predictions about volume and capacity. Even when not working in teams, the class sat close and comfortably together on an assortment of lawn chairs to discuss what they discovered during the lesson's activity.

Connections to life outside of school were also emphasized in the CGI-4/5 and both SFA lessons (See Figure 8). Many lesson examples, problems and materials were based on experiences outside school. The CGI-4/5 and SFA teachers were comfortable making connections to students' life out side of school, including, asking students to make connections themselves (e.g., "write about a time in your life when we might compare fractions to decide what to do." SFA-3 1:05:07).

The SFA teachers and the CGI-4/5 teacher moved to and among students, interacting one-on-one or with small groups, using a quiet voice (Privatization, see Figure 8). The CGI-3

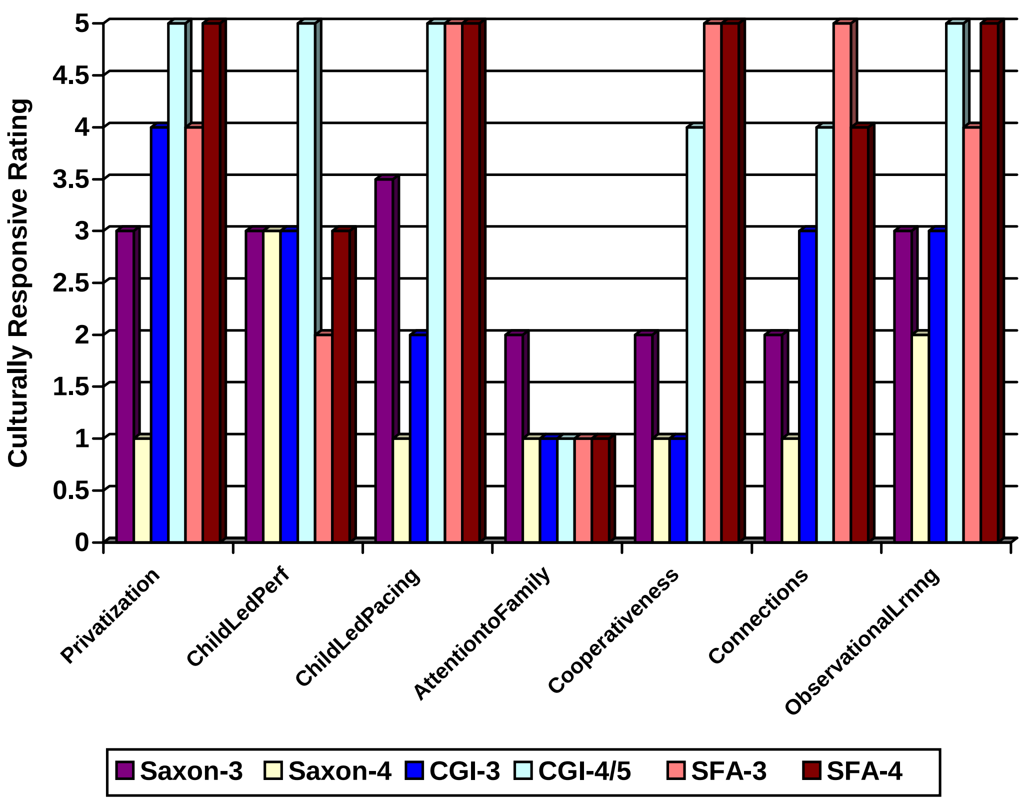

Figure 8. Cultural Responsiveness Rubric Item Scores

teacher also moved to and among students, interacting one-on-one and using a quiet voice.

Each also addressed the whole group, combining whole group presentation and more personal interaction styles. In contrast, Saxon teachers addressed the whole class from the front of the room, while students sat alone at their desks following along in their textbooks.

Helpfulness among students was encouraged in one of the Saxon classes, but cooperativeness was not emphasized in either Saxon lesson.

Attention to the importance of family was rarely evident in any of the six lessons. Only once did a teacher mention family and that was one of the Saxon teachers in the school on the reservation. Nor did an emphasis on child-led performance distinguish high- from low-culturally responsive lessons. All teachers mixed volunteer performance opportunities with teacher-requests. Thus, the instrument for rating cultural responsiveness was useful for six of the seven categories. In these six lessons, little connection to family was observed. Cultural responsiveness seems to be more readily influenced by the lesson context and individual teacher than the other ratings.

Eight items from the NCTM-based rubric on reform pedagogy were identified as also assessing cultural responsiveness. As seen in Table 6, on the basis of the NCTM-based ratings, the CGI-3 lesson is rated with greater cultural responsiveness. Ratings from the two rubrics are more similar for the other five lessons. The discrepancies highlight the varied indicators and possible conceptions of what cultural responsiveness means. The disagreement between the two rubrics center around *connections* and whether or not connections to out-of-school experiences is a defining feature of culturally responsive teaching for Native American students.

Table 6. Cultural Responsiveness Item Ratings from NCTM Rubric

Culture subscale based on NCTM Professional Standards Rubric	**Average ratings[18] per lesson**					
	Saxon-3	**Saxon-4**	**CGI-3**	**CGI-4/5**	**SFA-3**	**SFA-4**
1. *Connections* are made between math concepts, life/real world, other content.	1.5	1.0	3.75	3.75	2.0	2.0
2. Lesson helps students *connect* mathematics, its ideas, and its applications	0.5	0	2.5	4.0	2.5	3.5
3. Children are encouraged to work cooperatively.	2.25	1.0	2.5	4.0	4.0	4.0
4. Competition is de-emphasized.	1.75	2.5	3.25	4	1	1.5
5. Lesson encourages students to work together to make sense of mathematics.	0.5	0	2.0	4.0	4.0	2.5
6. Lesson is time-generous.	2.0	1.75	3.75	4.0	1.5	2.5
7. Lesson activities rely on primary sources of data and manipulative materials.	1.5	1.0	3.75	4.0	1.5	2.5
8. Teacher considers individual students' abilities.	2.0	1.25	4.0	4.0	1.0	1.0
Average Culture subscale	1.50	1.06	3.19	3.97	2.19	2.44
Overall Cultural Responsiveness Rating from other Rubric	**2.0**	**1.0**	**2.0**	**4.0**	**4.0**	**4.0**

[18] NCTM Rubric Ratings ranged from 1 = "lesson is not at all reflective of item" to 4 = "lesson is extensively reflective of item."

Student Aptitude and achievement

Average performance on the aptitude and achievement tests for each lesson case is reported as mean scores in the following tables. Both whole class and American Indian subgroup averages are provided in Tables 7 and 8.

With regards to nonverbal reasoning aptitude, across both grades and groups, the mean WRAT Nonverbal Reasoning scores were all within the average range, defined as between 15 standard score points above or below a standard score of 100 (Robertson, 2001). In two particular lesson cases, there was a great deal of variability in aptitude as indicated by the large standard deviations for CGI-3 and Saxon-4, for both for the class as a whole and for the subgroup of American Indian students.

With regards to math achievement, average ITBS® scores for each whole class, and American Indian subgroup, per lesson case, were compared to median (typical) performance levels for spring of the school year . In this manner, for each of the three ITBS® subtests, performance were coded at or above (+) or below (-) median performance levels and reported in Tables 9 and 10.

The ITBS® uses a scale representing achievement across a developmental continuum from kindergarten through ninth. Referred to as developmental standard scores, scores can be compared to typical performance of students in spring of the school year. A score of 185 and 200 correspond, respectively, to the typical (median) performance of 3rd and 4th graders, (Hoover, Dunbar et al., 2003, p. 15). Mean ITBS® scores at or above these typical end-of-grade performance levels are highlighted by shaded cells.

Table 7. Grade 3 Mean Aptitude & Achievement Standard Scores

Lesson Case		WRAT Nonverbal Reasoning	ITBS® Concepts & Estimation	ITBS® Problem Solving	ITBS® Computation
All Students					
SFA-3 (n=15)	M	100.32	**195.74**	**188.32**	**189.95**
	SD	12.70	18.94	21.99	17.03
	min–max.	75 - 122	167 – 227	153 – 229	147 - 216
CGI-3 (n=14)	M	113.57	**187.79**	**187.57**	181.79
	SD	19.37	19.92	21.35	13.01
	min-max.	77 – 145	146 – 227	143 – 229	160 - 202
Saxon-3 (n=15)	M	93.27	N/A[19]	N/A	N/A
	SD	14.55	N/A	N/A	N/A
	min-max.	75 - 115	N/A	N/A	N/A
American Indian Student Subgroup					
SFA-3 (n=8)	M	100.88	**193.63**	**187.1250**	**187.13**

[19] Data not available due to administration error.

	SD	13.82	19.91	24.42	21.16
	min-max.	75 – 118	167 – 227	158 – 219	147 - 216
CGI-3 (n=7)	M	113.14	178.57	175.57	177.86
	SD	20.38	17.61	17.64	12.25
	min-max.	84 – 141	146 – 197	143 – 192	163 - 197
Saxon-3 (n=15)	M	93.27	N/A	N/A	N/A
	SD	14.553	N/A	N/A	N/A
	min-max.	75 - 115	N/A	N/A	N/A

Table 8. Grade 4 Aptitude and Achievement Standard Scores

Lesson Case		WRAT Nonverbal Reasoning	ITBS® Concepts & Estimation	ITBS® Problem Solving	ITBS® Computation
All Students					
SFA-4 (n=18)	M	98.88	**206.50**	**202.17**	**205.50**
	SD	14.51	20.16	20.23	19.52
	min-max.	77 – 140	173 – 259	176 – 270	172 - 248
CGI-4/5 (n=9) (4th graders)	M	116.33	**206.44**	**216.22**	198.56
	SD	13.08	22.30	34.81	11.78
	min-max.	99 - 140	214 – 167	159 – 252	176 - 214
Saxon-4 (n=19)	M	105.79	193.06	195.17	196.94
	SD	20.25	15.17	17.29	19.70
	min-max.	87 – 101	194 – 200	194 – 200	172 - 211
American Indian Student Subgroup					
SFA-4 (n=5)	M	94.20	197.20	198.80	191.00
	SD	5.02	2.28	3.35	18.14
	min-max.	87 – 101	194 – 200	194 – 200	172 - 211
CGI-4/5 (n=8)	M	113.38	**206.75**	**211.75**	196.63
	SD	10.27	23.81	34.34	10.97
	min-max.	99 – 130	167 – 232	159 – 252	176 - 214
Saxon-4 (n=19)	M	105.79	193.06	195.17	196.94
	SD	20.25	15.17	17.29	19.70
	min-max.	71 – 145	159 – 218	159 – 218	158 - 230

As can be seen in Table 9, among the 3rd grade lesson cases, class averages, for the most part, were at or above the median performance levels for spring of the year. The class average in Computation and the American Indian subgroup averages in all three areas assessed, for the CGI-3 lesson case, were below median performance levels.

Table 9. Achievement in Relation to Median ITBS® Performance for 3rd Graders (spring)

	Concepts & Estimation	Problem Solving	Computation
Class Average			
SFA-3 (n = 15)	+	+	+
CGI-3 (n = 14)	+	+	-
American Indian Subgroup Average			
SFA-3 (n = 8)	+	+	+
CGI-3 (n = 7)	-	-	-

As can be seen in Table 10, class averages in the SFA-4 lesson case were above grade-level median performance, but the American Indian subgroup averages were not. In the CGI-4/5 case, both the class and American Indian subgroup averages for Concepts and Estimation and Problem Solving were above median performance for 4th graders in spring of the school year. In the Saxon-4 lesson case (with 100% of the class American Indian), none of the average ITBS® scores were above the median performance for 4th graders in spring of the school year.

Table 10. Achievement in Relation to Median ITBS® Performance for 4th Graders (spring)

	Concepts & Estimation	Problem Solving	Computation
Class Average			
SFA-4 (n = 19)	+	+	+
CGI-4/5 (n = 9) (4th graders only)	+	+	-
Saxon-4 (n = 19) (all American Indian students)	-	-	-
American Indian Subgroup Average			
SFA-4 (n = 5)	-	-	-
CGI-4/5 (n = 8) (4th graders only)	+	+	-

Patterns and Relationships For Findings

Comparing pairs of lesson cases across grade level revealed consistencies within each approach. As seen in Table 11, both CGI lessons emphasized problem solving, reasoning, and making connections. In relation to worthwhile mathematical tasks (NCTM standard of professional practice #1), the CGI lessons emphasized reasoning, connections and problem solving over computation and memorization of procedures. In relation to use of discourse (NCTM standards of professional practice #2, 3 and 4), the CGI lessons encouraged students to reflect on and discuss their own and other's thinking. Additionally, teacher's talk in the CGI lessons involved a balance of statements and questions, and, compared to the Saxon and SFA lessons, was characterized by the highest proportion of higher-order questions (over 20% of teacher utterances in both CGI lessons).

The two CGI lessons differed in terms of their cultural responsiveness. CGI-4/5 was rated high while CGI-3 was rated low. With regard to student achievement, in particular for American Indian students, in the CGI-4/5 lesson case, average subgroup scores were above grade-level in two of the ITBS®, Concepts & Estimation and Problem Solving, but below grade-level in Computation. This achievement pattern may be consistent with the findings regarding lesson emphasis on problem solving, reflection, and discussion, but other factors such as conditions of test administration and composition of the student group might influence the observed achievement levels. The same achievement pattern and profile was not evident in the CGI-3 lesson case where average American Indian ITBS® scores were below grade-level on each of the three subtests. Possible explanations for this pattern are numerous, including, the small numbers of students which are overly sensitive to individual variation.

Consistencies also were apparent within the SFA approach. Both SFA lessons, to a moderate degree, emphasized problem solving, reasoning and making connections. Both were rated high in terms of cultural responsiveness, in particular, with regard to cooperativeness. In both SFA lessons, students frequently worked and discussed in teams and pairs. Teacher questions in the SFA lessons, however, were more likely to prompt recall and retelling rather then explanation. The teacher's talk emphasized explicit telling statements (over 75% of teacher utterances in each SFA case), and when posing questions, equal proportions of lower-order (Knowledge) and higher-order (Comprehension, Application, Analysis, Synthesis and Evaluation) questions were asked.

In the SFA cases, achievement for the American Indian subgroups were mixed. Average American Indian subgroup achievement was above grade-level in SFA-3, but below grade-level in SFA-4. The American Indian subgroups were small (8 and 5 students, respectively) and one student (in SFA-3) received special education services.

As can be seen in Table 11, Saxon lessons consistently failed to emphasize problem solving, reasoning, nor making connections. Consistent with the Saxon approach, teacher's telling statements in both Saxon lessons explicitly told students when and how to do procedures. Cooperativeness was not emphasized in either of the Saxon lesson cases and overall cultural responsiveness ratings were low. Low cultural responsiveness ratings may be related to the fact that Native culture in the school is taught separate from core academics in a separate Native language course. Additionally, given that the community is a tribal community, community preference may be an emphasis on academic content and achievement in the mathematics curriculum and program. Achievement, available only for Saxon-4, was below median grade-level performance.

Table 11. Summary of Findings Regarding Quality of Lesson Case Dimensions

Lesson Case	Emphasis on Problem Solving, Reasoning and Making Connections				Cultural Responsiveness	Student Achievement	
	Tasks	Pedagogy	Tell/Question Ratio	Question Quality		Class	Am Ind.
SFA-3	~	~	-	~	+	+	+
SFA-4	~	~	-	~	+	+	-
CGI-3	+	+	+	+	mixed	~	-
CGI-4/5	+	+	+	+	+	~	~
Saxon-3	-	-	-	-	-	N/A	
Saxon-4	-	-	-	-	-	-	

Symbol Key

- \- low quality
- ~ moderate quality (for achievement, so-so was defined as 2 or 3 subtest mean scores above median grade-level performance)
- \+ high quality (for achievement, high quality was defined as each of 3 subtest mean scores above median grade-level performance)
- NA not available

Across the lesson cases, American Indian students, on average, did not reach grade level performance. There are many possible explanations for the different patterns of achievement observed across cases and approaches, including, factors related to curriculum coverage, composition of the classroom groups of students, the small numbers of students, individual student aptitude and ability, test administration conditions, community context, and extent of teacher experience with the adopted approach.

DISCUSSION

Although the lesson cases presented situated portraits of the instructional experiences of American Indian students in mathematics classrooms, the cases are limited in number and representativeness. By treating each lesson holistically, the complexity of factors potentially influencing teacher-student interactions and student achievement is more likely to be appreciated (Patton, 2002), but the generalizability of the findings is limited. Also, although multiple data sources were used to corroborate findings and interpretations, and student engagement was evident in the videotaped lessons, a limitation of the present study is the omission of systematically collecting student engagement data and data on attitudes and beliefs about learning mathematics from their own and their families' perspectives.[20]

Nevertheless, this study was designed to develop understanding of key variables and processes in mathematics instruction for and achievement of Native American students. The study design facilitated collection of data from multiple sources and information-rich subjects on the belief that cases would provide robust data sets for analysis. This was indeed the case.

Developers' program descriptions, teacher reflection, and videotaped lessons and transcripts provided complementary perspectives on the actual implementation of three different approaches to teaching mathematics. Separate rubrics provided multiple perspectives on the quality of interactions and content across different math lessons. These and other data collection tools revealed both reliable and less reliable similarities and differences between lesson cases and help establish the identity of key variables, and methods for their measurement, in classroom instruction for American Indian students.

Defining and studying culturally responsive instruction for American Indian students remains a challenge for present and future researchers. In addition to resolving discrepancies in the substance and measurement of such dimensions of practice as cooperativeness, making connections, and child-led pacing, further input and discussion of critical dimensions and how they manifest themselves in practice is needed in collaboration with Native individuals. Recently, for example, an informal review of the present researcher-developed culturally responsive rubric was conducted with a group of 10 Native educators attending a National Indian Education Association (NIEA) conference session (Denver, Colorado, October 8, 2005). Reviewers at this NIEA session identified the following dimensions as missing from our present rubric: encouraging and supporting story telling, use of culturally-specific examples (e.g., designing a corn field instead of a square), and emphasis on universal Native values (e.g., generosity, critical thinking, and respect). Several participants also indicated that culturally responsive teaching, in addition to incorporating Native content, might also be conceived as good teaching, emphasizing cooperativeness, for example, good teaching for all students.

It must be stressed that these analyses represent information gleaned through a narrow lens, and the researchers stress that these analyses are presented in context. It was not the purpose of this study to advocate one curricular or instructional approach over another; rather, information from these varied curricular and informative contexts should be used as the basis for further study of how to best configure the mathematics instructional experience of Native American students.

Present findings suggest that the extent to which cooperativeness and helpfulness are the norm in a mathematics classroom ought to be a key variable of study. Cooperation, egalitarianism, and informality are important values and dispositions in most American Indian groups (Cajete, 1997; Gillian, 1999); and in the present study, these were the norms in the most highly-rated culturally responsive lessons. As an independent variable, an

[20] Surveying students and families was beyond the scope of this study.

emphasis on cooperativeness has a strong research-base supporting its likely impact for other minority students and mainstream groups as well (Slavin, 1995; Johnson and Johnson, 1989).

Among the three highly-rated, culturally-responsive lessons, two different approaches to teaching mathematics were used, and only in one of the cases, there was evidence that American Indian students as a subgroup performed at or above grade-level on each of three measures of mathematics achievement. Although the number of cases is too few to draw definitive conclusions, these findings are consistent with the view that there is *no* single best approach. Good teachers need to learn how to make adaptations, regardless of adopted curriculum or approach, in order to meet the goal of all students achieving at the highest possible levels. This learning occurs on the job and cumulatively with experience teaching and seeing students respond. Discrepancies between results of different rating instruments also highlighted the need for further development of measures, particularly with regard to the construct of cultural responsiveness for American Indian students in mathematics classrooms.

The ratio of telling/question utterances and the relative proportions of higher order questions is largely consistent within approach, but not within grade. This suggests that teacher's talk is driven by the expectation of the approach rather than by attributes unique to a particular grade level. In other words, teacher-talk to 3rd graders is not consistent, suggesting that the unique attributes of 3rd graders for instructional decision making either do not exist or are not recognized. However, teacher's talk within instructional approach is very consistent across grades, suggesting that the unique characteristics of each approach are recognized and adhered to by teachers.

In three of the five lesson cases with available data, American Indian students, as a subgroup, performed below grade-level norms in each of the areas of mathematics assessed. This finding is consistent with other reports indicating that American Indian student performance is not on par with desired levels of achievement. In one case (SFA-3), American Indian students, as a subgroup, performed above grade-level norms in all three mathematics subtests. In a second case (CGI-4/5), American Indian students, as a subgroup, performed above grade-level in two subtests, Concepts & Estimation and Problem Solving, but not in Computation. Reasons for varying performance levels are many, including demographic characteristics of the community. The SFA-3 case, in fact, was situated in a school serving a moderate-income, not a high-poverty community.

Teachers and school administrators have no control over community characteristics; and thus, it is of little value to examine what might be changed in a community in order to improve student achievement. On the other hand, teachers and administrators do have control over the learning environments and approaches to teaching in their school. Consideration of the CGI-4/5 lesson case as a demonstration of *what is* as well as *what could be* in a high-poverty school may suggest fruitful areas for making changes.

The second pattern of convergence was the preponderance of telling statements across all of the lesson cases. The high proportion of telling statements in the CGI lessons was particularly surprising given the emphasis of this approach on listening to and understanding children as they talk about their thinking (Franke & Grouws, 1997). True, teacher's talk in the CGI lessons was characterized by proportionally more question posing than teacher's talk in SFA lessons, which in turn was higher than that in Saxon lessons, indicating consistency within approach. Accordingly, students in the CGI and SFA lessons may have had more opportunities to practice and development mathematical reasoning. Yet, the preponderance of telling statements suggests that telling is necessary to teaching, and that judicious and/or purposeful telling may be a valuable choice of action in a teacher's repertoire.

Teachers in the present study used statements to redirect student's attention to the task at hand, define mathematical terms, restate or reformulate student's statements to elucidate understanding or misunderstanding, and for a host of other reasons. Other researchers, notably, Lobato, Clarke and Ellis (2005), have shifted the focus on telling, from the "form of a teacher's action to its function" (p. 131). This shift appropriately "attaches priority to the development of the students' mathematics, rather than to the communication of the teacher's mathematics." (p. 131). How, for example, do teachers effectively use telling statements to help students formulate an explanation or articulate their thinking in ways that promote higher achievement; and does the effectiveness vary with subgroups of students? This is an area for further investigation necessary to inform the selection of content to be used in professional development aimed at improving the quality and outcome of the instructional experience of Native American students.

Mathematics reform emphasizes equity and excellence for all students; yet, much of the knowledge available about how to accomplish these goals is ideological or policy-based rather than empirical. Ideological and policy-based guidance is important, but is incomplete without research-based guidance. In this study, research-based patterns and relationships were identified through a comparative lesson case study. The findings suggest areas of focus that have the potential to generate foundational knowledge for practical guidance. In particular, findings suggest focusing on cooperativeness in the classroom environment, and how teachers effectively use verbal interactions and other instructional moves to advance students' mathematics knowledge and skills.

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APPENDIX A

Lists of Research Partnership and Advisory Panel Members

Research Partnership

Rose-Marie Davis, School Improvement Specialist, Turtle Mountain Agency, ND
Teresa Delorme, Principal, Pioneer Elementary School, Bismarck, ND
Lori Gibson, Math Staff Developer, Bismarck Public Schools, ND
Jean M. Hall, Principal, Edwin Loe Elementary School, New Town Public School District, ND
Kathy Jo Henry, Instructional Coordinator, Ojibwa Indian School, Belcourt, ND
Elaine Incognito, Principal, Twin Buttes School, Three Affiliated Tribes, ND
Willa Incognito, Sixth-Grade Teacher, Twin Buttes School, Three Affiliated Tribes, ND
Jen Janecek, UTRSI Director, United Technical Tribal College, Bismarck, ND
Ellen Knudson, Math Staff Developer, Bismarck Public Schools, ND
Gene La Fromboise, Superintendent, Standing Rock Community Schools, ND

Advisory Panel

Donna Dehyle, Ph.D., University of Utah
Gerald R. Fast, Ph.D., University of Wisconsin-Oshkosh
Cheryl M. Kulas, Director, North Dakota Indian Affairs Commission

Minority Interns

2002 - Nicole Bowman, Owner Bowman Consulting, Wisconsin
2003 – Teresa Delorme, Pioneer Elementary School, Bismarck, North Dakota
2003 - Gene La Fromboise, Turtle Mountain RSI, Belcourt, North Dakota
2004 – RunningHorse Livingston, Middleton, Wisconsin
2005 – RunningHorse Livingston, Middleton, Wisconsin

Visiting Scholar

2004 – Judith Hankes, Ph.D., University of Wisconsin-Oshkosh
2005 – Judith Hankes, Ph.D., University of Wisconsin-Oshkosh

APPENDIX B

Examples of Statements and Questions in Saxon Lesson Teacher's Talk

Saxon teachers typically made statements telling students explicitly when and how to do procedures.

Saxon-3 (9:02): "Put a one in the ones place, and then put a one above here (pointing). Now you're going to count, one, two, three. Put it in front of the one."

Saxon-4 (21:55): "So you can't just multiply two times three plus four. You have to do one problem first, right? OK, so we did what was in parentheses first. All through your math that's what it's going to be, anytime you run into something with parentheses, that's what you're going to do first."

Examples of Statements and Questions in CGI Lesson Teacher's Talk

Teacher's talk in the CGI lessons was characterized by elucidation of background knowledge and other cognitive processes. Telling statements in the CGI classrooms served the function of clarifying task expectations rather than telling students how to carry out particular procedures.

CGI-4/5 (2:13): "Over the last couple of weeks …we've spent a lot of time looking at various objects and their volumes. Containers, boxes, we found the volume of the room. You guys brought in many containers from home. So I want us to use some of the skills that we have developed over the last month or so in predicting and what we know about volume and what we know about space, and I'm going to ask each of your groups to take one of these boxes which I have put together, some of the containers you brought from home and a couple that I found, and I'm going to ask you to take a look at these with the other members of your group and I want you to predict the order of containers from least to greatest alright?"

Examples of Statements and Questions in SFA Lesson Teacher's Talk

Statements in the teacher's talk recorded in the two SFA lessons were comprised of a combination of statements directing students how to carry out a task individually or as a team and how to carry out particular mathematical procedures, statements that made connections explicit, and statements that guided the students through a solution process. Additionally, teacher's talk in the SFA lessons was unique in the number of 'cheers' used to celebrate individual and group success. Related to the use of cheers, in one of the SFA lessons, the teacher used a point system where points were awarded to teams for success. The different types of statements are illustrated in the excerpt that follows.

SFA-3 (6:58): "All right, when Pryia is finished how many staples are left in the box? Underline that. I want you to think about how you are going to solve that? We know there

> are 1500 staples in a box, and there's 143 tests. Think about how are you [sic] going to solve this problem? Think. I want you to share with your partner how you are going to solve, and then you are going to solve – listen, don't discuss yet. You're going to solve, you're going to discuss with your partner, you're going to solve, and then you're going to discuss in your team. ... And I'm only going to give you four minutes to do this. You really need to work hard so that we can complete our tasks. Discuss with your partner, what operation? Okay, begin."

SFA-4 (29:00): "Now, keep your paper, keep your pencil, because we're going to focus on division and start simplifying. We're gonna simplify, simplify. And you already have a taste of this from yesterday. You just modeled it right here in our warm-up. So we are a step ahead. This is going to be a piece of cake. Speaking of cake, take out a piece of paper. Cake and pie, and oh, also, we've talked about fractions are part of a whole, such as a pie. ... What other examples? What else can we divide equally?"

APPENDIX C

STUDENT PERFORMANCE

Results of the lesson rating with respect to adherence to NCTM (1991) standards of professional practice are organized and presented in detail in Table C-1 below:

Standard 1: worthwhile mathematical tasks;

Standard 2: use of discourse;

Standard 3: learning environment; and

Standard 4: analysis of teaching and learning.

Table C-1. Average ratings of each lesson according to NCTM's professional standards

Standard and Item	Lesson Rating					
Worthwhile mathematical tasks (Standard #1)	**Saxon-3**	**Saxon-4**	**CGI 3**	**CGI-4/5**	**SFA 3**	**SFA 4**
Lesson emphasizes mathematical reasoning	1.0	1.5	4.0	4.0	1.5	2.0
Connections are made between math concepts, life/real world, other content.	1.5	1.0	3.75	3.75	2.0	2.0
Lesson emphasizes problem solving rather than computation and memorization of procedures.	1.0	1.5	4.0	3.5	1.5	1.75
Lesson helps students learn to reason mathematically.	0.5	0.5	3.75	4.0	1.0	2.0
Lesson encourages students to conjecture, invent and solve problems.	0	0.25	3.5	4.0	1.0	1.0
Average of Worthwhile mathematics tasks:	0.8	0.95	3.8	3.85	1.4	1.75
Use of discourse (Standards #2, 3, & 4)	**Saxon 3**	**Saxon-4**	**CGI 3**	**CGI-4/5**	**SFA 3**	**SFA 4**
Students are encouraged to reflect on and discuss their own and other's thinking.	1.5	1.0	4.0	4.0	2.5	3.0
Teacher teaches concepts	1.25	2.0	3.75	4.0	2.0	2.25

by posing higher order questions rather than direct instruction.						
Use of discourse (Standards #2, 3, & 4)	**Saxon 3**	**Saxon-4**	**CGI 3**	**CGI-4/5**	**SFA 3**	**SFA 4**
Lesson fosters student development as independent problem solver, to rely more on him/herself to determine whether something is mathematically correct.	0.5	0.5	3.25	4.0	1.5	1.5
Lesson helps students connect mathematics, its ideas, and its applications.	0.5	0	2.5	4.0	2.5	3.5
Average of Use of discourse:	0.94	0.88	3.38	4.0	2.13	2.56
Learning environment (Standard #5)	**Saxon 3**	**Saxon-4**	**CGI 3**	**CGI-4/5**	**SFA 3**	**SFA 4**
Children are encouraged to work cooperatively.	2.25	1.0	2.5	4.0	4.0	4.0
Competition is de-emphasized.	1.75	2.5	3.25	4.0	1.0	1.5
Lesson is time-generous.	2.0	1.75	3.75	4.0	1.5	2.5
Lesson encourages students to work together to make sense of mathematics.	0.5	0	2.0	4.0	4.0	2.5
Average of learning environment:	1.63	1.31	2.88	4.00	2.63	2.63
Analysis of teaching and learning (Standard #6)	**Saxon 3**	**Saxon-4**	**CGI 3**	**CGI-4/5**	**SFA 3**	**SFA 4**
Lesson activities rely on primary sources of data and manipulative materials.	1.5	1.0	3.75	4.0	1.5	2.5
Assessment is interwoven with teaching and occurs through questioning and observation of student work.	1.0	2.0	3.5	4.0	2.75	4.0
Teacher considers individual students' abilities.	2.0	1.25	4.0	4.0	1.0	1.0
Average of Analysis of teaching and learning:	1.50	1.42	3.75	4.00	1.75	2.50

APPENDIX D

Approach Descriptions

Saxon Math

Overview

In the Saxon approach "mathematics … is a cognitive structure that builds upon itself" (Hake & Saxon, 2004, p. T12)[21]. Mathematics is a foundation for the challenges of everyday life. "The ultimate height and stability of the mathematical structure within each individual is determined by the strength of the foundation" (Hake & Saxon, 2004, p. T12). Saxon Publishers' mission is to ensure that all students have access to instructional materials with proven records of success[22]. Saxon focuses on results, both tangible (i.e., test results) and intangible (i.e., "light-bulb" moments). Based on research, Saxon's mathematics approach includes three main elements: Incremental instruction; continual practice and review; and frequent and cumulative assessments. These three components are distributed across grade levels.

Theory of Learning (Student's Role)

According to John Saxon, " 'Mathematics is not difficult. Mathematics is just different, and time is the elixir that turns things different into things familiar.' [The Saxon] program provides the time and experiences students need to learn the skills and concepts necessary for success in mathematics, whether those skills are applied in quantitative disciplines or in the mathematical demands of everyday life" (Hake & Saxon, 2004, p. T13)[23]. Children "develop greater insights through frequent exposure to concepts and gain a stronger grasp of information through repeated experiences" (Hake & Saxon, 2004, p. T12). According to Saxon Publishers students should work, as much as possible, on the prescribed problems throughout the curriculum. Ample opportunity is given to students to practice problems related to current content as well as content covered during previous lessons.

Theory of Instruction (Teacher's Role)

As explained earlier, the Saxon mathematics approach includes three main elements: Incremental instruction; continual practice and review; and frequent and cumulative assessments. These components are distributed across grade levels.

Incremental instruction. Based on research that indicates that smaller pieces of information are easier to teach and easier to learn, Saxon Math breaks complex concepts into smaller, related increments. Each increment builds on the foundation of previous increments,

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21 Hake, S. & Saxon, J. (2004). *Saxon Math 5/4, Third Edition, Teacher's Manual, Volume 1.* Norman, Oklahoma: Saxon Publishers.

22 Information about Saxon Publishers materials and educational philosophy come from Saxon's website http://www.saxonpublishers.com/school/math/index.jsp

23 Hake, S. & Saxon, J. (2004). *Saxon Math 5/4, Third Edition, Teacher's Manual, Volume 1.* Norman, Oklahoma: Saxon Publishers.

leading students to the development and understanding of mathematical concepts. In Saxon Math, concepts are taught and developed over time. Students are not expected to completely understand complex concepts the first time they are presented. New concepts are distributed throughout the year along with the previously learned concepts. According to the Saxon approach, incremental instruction distributed across the level results in greater student achievement[24].

Continual practice and review. Saxon Publishers believe that students learn by doing and practicing the problems themselves. "Continual practice and review means that fundamental skills and concepts are practiced and reviewed throughout the year," helping students in the retention of concepts (Wrigley, 2004). Saxon Publishers recognize that many mathematical skills take time to develop and that students need time to learn the skills and concepts necessary for success in mathematics (Hake & Saxon, 2004). The continual, distributed practice provide students with the opportunity to develop and master math skills and ensuring long-term memory of concepts. Each problem set supplied in the Saxon curriculum contains only a few problems that practice new increments, while the remaining problems provide practice of concepts previously presented. Practice of increments is distributed continually across each grade level.

Frequent and cumulative assessments. Saxon math assessments are cumulative and frequent, and assess both the acquisition and maintenance of concepts. Assessments are built into each fifth lesson so teachers can have a frequent gauge of students' progress. Tests are cumulative in content allowing teachers to monitor students' retention of skills (as opposed to assessments related only to content covered since the last test).

Identification as Constructivist or Explicit Instruction approach

Saxon Publishers identify their Mathematics curriculum as explicit instruction (Saxon Publishers, n.d.)[25]. Hall (2002, cited by Saxon Publishers, n.d., p.11)[6] describes Saxon's explicit instruction as a systematic approach that includes a set of delivery and design procedures based on educational research. According to Arens (2002)[26] explicit instructions are characterized by the somewhat scripted teaching of incremental and discrete skills. As Lewis, Wilson, & McLaughlin (1992, cited by Arens, 2002) indicate, explicit instruction models represent a structured approach to teaching which uses scripted formats, extended practice, and review. This type of instructional approach follows a fast pace of instruction that leads students through a process and teaches them to use that process as a skill to master other academic skills. Arens identifies independent practice, memorization of vocabulary or computations, and use of worksheets and guided practice as typical components of explicit instruction. The role of the teacher in explicit instruction approaches is as bearer of knowledge and skills.

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[24] http://www.saxonpublishers.com/school/math/index.jsp;jsessionid=82545BE278D9BAEEBC86AB05CE3C6484

[25] Saxon Publishers (n.d.). *Scientific research base for Saxon Math K-12. Foundational research and program efficacy studies.* Retrieved May 13, 2005 from: http://www.saxonpublishers.com/pdf/research/saxon_math_research.pdf

[26] Barley, Z., Lauer, P., Arens, S., Apthorp, H., Englert, K., Snow, D., & Akiba, M. (2002). *Helping at-risk students meet standards. A synthesis of evidence-based classroom practices.* Aurora, CO: McREL.

Content

Success of the Saxon approach is described in all publicly available Saxon literature as based on the pedagogical strengths of the approach (distributed incremental instruction). Content by itself is not the focus of the publishers' information, the emphasis of the Saxon program is in the processes of teaching and learning.

Content in the Saxon approach is distributed throughout the grade levels (K-8). Each grade level is organized in over 100 lessons, covering concepts that may repeat throughout the year with increasingly complex content (e.g., telling and showing time to the hour, to the half hour, to five-minute intervals; addition facts, adding 0, adding 1, sums of 10, adding 2, adding 9, adding 3 and 4; writing fractions using the fraction bar, writing a fraction to show a part of a set, writing a part of a set as a fraction, writing a fraction to show a part of a whole, etc.). Students are expected to understand the content through distributed instruction and distributed practice.

Through the emphasis on scripted recommendations in its explicit instruction approach Saxon Math "provides daily opportunities for students to develop mathematical proficiency in conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition" (Saxon Publishers, n.d., p. 4)[27]. These five interwoven and interdependent strands of mathematical proficiency were identified and reported in 2003 by the National Research Council (*Adding it up: Helping children learn mathematics*, cited by Saxon Publishers, n.d., p.4) as research-based recommendations for mathematical proficiency.

Classroom implementation and structure

In each Saxon program concepts are presented in sequenced small pieces or increments. New objectives are introduced through specific group activities, and all concepts are practiced in each succeeding lesson. All areas of mathematics are integrated to help students see the interrelationships of the concepts. Concepts are not presented in chapters, but are introduced and practiced over a period of time. In Saxon Math 3 concepts are practiced daily during math meetings, written practice, and facts practice activities. In Saxon Math 5/4 concepts are practiced during warm up, lesson practice and mixed practice. Saxon Math 3 includes 135 lessons, 26 written assessments, and 13 oral assessments. Saxon Math 5/4 consists of 120 daily lessons, 12 activity-based investigations, and 23 tests.

Cognitively Guided Instruction

Overview

Cognitively Guided Instruction (CGI) is not a curriculum, but rather, a "group of concepts or philosophy" (Knapp & Peterson, 1995, p. 45). It is an approach to teaching based on the assumption that children have mathematical knowledge and that instruction should build on that knowledge (Knapp & Peterson, 1995). The defining features of CGI are teachers learning how children learn and using that knowledge for instruction (Peterson, Fennema

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[27] Saxon Publishers (n.d.). *Scientific research base for Saxon Math K-12. Foundational research and program efficacy studies.* Retrieved May 13, 2005 from: http://www.saxonpublishers.com/pdf/research/saxon_math_research.pdf

& Carpenter, 1991). The approach was developed by researchers who studied and described children's development of mathematical concepts and reasoning and invited teachers to share in the interpretation and application of their research.

Theory of Learning (student's role)

Four premises underlie the logic CGI:

1. children naturally attempt to model problems as a way to make sense out of a situation,

2. children's modeling strategies develop in a fairly predictable fashion toward more sophistication,

3. problem solving contexts are powerful learning opportunities for developing mathematical concepts and skills, and

4. teachers have knowledge of children's mathematical thinking, but it tends to be fragmented and underutilized by teachers.

To help teachers develop more useful and coherent knowledge of how children think and develop mathematically, the developers of CGI studied how children naturally modeled problems (Carpenter, Fennema, Franke, Levi & Empson, 1999). Developing understanding is constructing ideas and building connections and hierarchies of relationships. From this view of mathematical development, a student would rarely if ever be characterized as "possessing no understanding. Almost always an individual has some pieces of knowledge that are relevant to her understanding of the mathematics. As teachers, we need to find out what the students do know and understand so that it can be built on" (Franke & Grouws, 1997, p. 315). Also, students are expected to learn from one another by watching and listening to other students' demonstrations and explanations of their strategies and thinking.

Theory of Instruction (teacher's role)

"The purpose of CGI is to expose elementary teachers to the research on mathematics students' learning and allow them to explore how they might use this knowledge in their daily instructional decisions" (Cwikla, 2004, p. 322). Cognitively Guided Instruction provides teachers with two frameworks based on research on children's mathematical development. One framework categorizes addition/subtraction word problems into eleven types, based on differences children notice and describe (Knapp & Peterson, 1995). The other framework describes type of strategies that children tend to develop as they progress from using concrete modeling and counting strategies to ward using their knowledge of remembered addition and subtraction number facts to solve problems" (Knapp & Peterson, 1995, p. 41).

The teacher is ultimately responsible for facilitating children's construction of mathematical knowledge. In this role as facilitator or guide, instruction "centers not around teacher presentations but around children's own knowledge and developing understandings"

(Knapp & Peterson, p. 42). Carpenter, Fennema, Franke, Levi and Empson (1999) describe the teacher's role as follows:

"A CGI teacher's role is active. CGI teachers continually upgrade their understanding of how each child thinks, select activities that will engage all the children in problem solving and enable their mathematical knowledge to grow, and create a learning environment where all children are able to grow, and create a learning environment where all children are able to communicate their thinking and feel good about themselves in relation to mathematics" (Carpenter, Fennema, Franke, Levi & Empson, 1999, p.101).

Teachers adopting a CGI approach, encourage students to solve problems in different ways and listen to their students' verbalizations as they describe and explain how they solved problems. Teachers use the two frameworks, the one categorizing problem types and the one categorizing children's strategies, to help them understand what individual children understand and decide on their next instructional move (e.g., what questions to ask, what kinds of problems to pose, what to demonstrate, what connections to help the child make).

Teachers who effectively adopt CGI for mathematics teaching do not have distinctive classroom environments per se, but rather are distinctive for their ability to talk specifically "about their children's solution strategies and how these strategies fit with the development of understanding" (Franke & Grouws, 1997, p. 322).

Identification as Constructivist or Explicit Instruction Approach

Cognitively Guided Instruction adopts a constructivist view of learning. The core idea of CGI's theory of mathematical understanding is that understanding develops by constructing relationships (Carpenter, Fennema, Franke, Levi & Empson, 1999). Teachers ask questions that focus children's attention on relationships between number and relationships between less and more mature problem solving strategies. Adequate preparation for taking on the responsibility of facilitating children's construction of relationships and mathematical understanding takes time; CGI teachers report that they "continually grow in their abilities to use their children's knowledge to select problems, to question children in a way that both elicits their thinking and helps them in problem solving, and to understand their children's thinking ((Carpenter, Fennema, Franke, Levi & Empson, 1999, p. 103).

Classroom Implementation and Structure

Cognitively Guided Instruction provides no "materials or specifications for practice;" it is a way of approaching mathematics that can supplement any curriculum. "Teachers develop their own instructional materials and practices from watching and listening to their students and struggling to understand what they see and hear" (Franke, Carpenter, Levi & Fennema, 2001), p. 657). Learning activities are problem-based. Children learn skills and number facts and develop mathematical understanding while solving problems when "each child is actively involved in deciding how best to resolve a mathematical situation" (Carpenter, Fennema, Franke, Levi & Empson, 1999). The mathematical situations or problems are often set in story contexts but also are set in such tasks as writing number sentences, finding multiple solutions, or discussing one or more mathematical concepts. When selecting problems, depending on what they understand about individual children's development, teachers decide how easy or difficult and how concrete or difficult to make a problem for individual children.

Teachers using CGI ask students to report on their thinking which allows teachers to better understand their students and exposes students to a variety of strategies, including more advanced strategies. Teachers ask students questions that encourage thinking about relationships.

Teachers and school teams who adopt CGI are encouraged to participate in a CGI professional development program. Such a program is a series of institutes and on-site follow-up support and leadership opportunities (see Comprehensive Center Region VI CGI Institutes (http://ccvi.wceruw.org/ccvi/CGISpider). Participation provides ongoing access to knowledge about children's developing understandings in mathematics which then serves as the background knowledge teachers need to teach for understanding regardless of a particular teaching style or the mathematics curriculum adopted by a school.

The Comprehensive Center Region VI offers three CGI Institutes annually, the CGI Basic, Advanced and Algebra Institutes. The basic institute is designed for kindergarten through third grade teachers with no prior CGI experience, and those who work with such teachers. The Advanced Institute is for people who have attended at least one 30-hour institute and have used CGI principles for at least one year with children and/or teachers. The Algebra Institute is for first through sixth grade teachers and those who work with them.

To some reformers, Cognitively Guided Instruction (CGI) exemplifies standards of effective pedagogy for all students across all subgroups (Tharp, Estrada, Dalton & Yamauchi, 2000). To some extent, experimental and other research clearly supports the efficacy of CGI for improving instruction and achievement in mathematics (Carpenter, Fennema, Peterson, Chiang & Loef, 1989; Hankes, 1998). Professional wisdom holds that students in classrooms taught by teachers using CGI develop a strong sense of confidence and ability to reason in mathematics (Apthorp & Woempner, 2004; LaFromboise & Rasmussen, personal communications, 2004). By design, CGI is an approach that builds on students' intuitive knowledge and reasoning and helps teachers learn how students learn (Peterson, Fennema & Carpenter, 1991); as such, CGI aligns well with the goals of American Indian education.

Success for All/MathWings

Overview

MathWings is a comprehensive K-6 mathematics program developed by the Success for All Foundation. It was designed as a component of the comprehensive school reform approach Success for All (Madden, Slavin, & Simons, 1999). MathWings is based on the National Council of Teachers of Mathematics' (NCTM) principles of effective mathematics instruction and assessment and on the principles of cooperative learning.[28] This program was designed to meet the needs of teachers who asked for a constructivist approach that

[28] From: Success for All Foundation. (n.d.). *Elementary – MathWings*. Retrieved October 3, 2005, from http://www.successforall.net/elementary/mathwings.htm

provides student materials, assessments, teachers' manuals, professional development, and other supports (Madden et al., 1999).

According to Slavin and Madden (Slavin & Madden, 2001), the structure that MathWings provides in the classroom allows students of all abilities and levels of knowledge to "experience the depth, breath, and beauty of mathematics" (p. 210). The intention of the designers of this program was to give all students "the opportunity to establish a solid foundation in mathematics [and to] extend and stretch their knowledge and experience in mathematics" (p. 210) to be able to develop the ability to use mathematical reasoning to solve problems and confidently explain their reasoning.

According to the Success for All Foundation, MathWings uses exploration, experimentation, and communication to actively engage students in problem solving experiences. Based on the NCTM's Principles and Standards for School Mathematics, MathWings advocates: problem solving rather than rote calculation; mathematical reasoning and representation; the use of calculators to develop concepts and focus on exploration for problem-solving; emphasis on communication to clarify, extend, and refine the students' knowledge; the development of metacognitive strategies; the use of alternative assessments that incorporate communication and calculation; connections with literature and other content areas to help students develop concepts in meaningful contexts; and cooperative learning to help all children succeed in mathematics (Slavin & Madden, 2001; (Success for All Foundation, 2004).

The program MathWings has two primary forms, Primary MathWings for grades 1 and 2, and Intermediate MathWings that covers grades 3 through 5 (Slavin & Madden, 2001). Each of these forms use routines, procedures and teaching methods appropriate to the students' age levels. The description that follows focuses on the Intermediate MathWings program[29].

Theory of learning (student's role)

MathWings attempts to "actively involve students in the conceptual development and practical application of their mathematical skills" (Slavin & Madden, 2001, p. 204). To develop mathematical thinking, students are presented with real-world mathematical problems and are first involved in their solution with the use of manipulatives, then representing problems and solutions in pictorial form, and eventually with formal mathematical language and symbols. This process helps students develop and take ownership of mathematical concepts. A premise of the MathWings program is that when students arrive at the school they already are familiar with a great deal of mathematical knowledge. The focus of the program is then to formalize and expand this knowledge by moving from concrete to symbolic representations through demonstrations and discovery which help students build mathematical understanding.

Language and communication are emphasized in MathWings because it is through developing their own problem solving methods and explaining their thinking to their classmates and to the teacher that students build mathematical understanding. Students in

[29] The Elementary and Intermediate MathWings programs are based on the same principles of learning and instruction, but their actual implementation may vary depending on the age and grade level of the students. The information here presented is not exclusive to the Intermediate program.

this program "constantly explain and defend their reasoning and solutions orally and regularly write in their logbooks" (Slavin & Madden, 2001, p. 205).

In MathWings students are allowed the use of calculators so they can think more about math and the processes to solve problems. Calculators allow students to "focus their energy on mathematical reasoning rather than on mere mechanical calculations" (Slavin & Madden, 2001, p. 205). Calculators are used as tools to support the development of concepts and the exploration of advanced problem-solving situations. With more time to think, students can try various solution approaches and then check their responses with the calculator, which in turn provide positive reinforcement when the solution is correct. Students are expected to develop their estimation skills and to predict outcomes that can be then checked with the calculator. This also allows students to understand that the information obtained through the calculator is "only as accurate as the information and process that is keyed into it" (Slavin & Madden, 2001, p. 206).

Theory of instruction (teacher's role)

According to Slavin and Madden (2001), the MathWings program presents a balance between mathematical conceptual development, solving of real problems, and maintenance of mathematical skills. MathWings uses cooperative learning and frequent assessment of the students' progress in understanding and using mathematics. In MathWings, cooperative learning is used so students of mixed-ability work in teams of four with the purpose of learning. The team's work is not complete until all members have learned the material being studied; this structure creates a positive interdependence among team members. Through cooperative learning teams do not compete against each other, instead, the team success depends on the individual learning of all team members. MathWings incorporates three key components of cooperative learning strategies: team recognition for achieving or going beyond a designated standard; individual accountability by demonstration of knowledge on individual assessments; and equal opportunities for success by contributing points to the team for the students' individual performance, doing their homework, and meeting behavioral goals set by the teacher (Slavin & Madden, 2001).

Assessment is an integral part of the MathWings program and it is performed in various ongoing formal and informal manners. To assess understanding teachers conduct observations of students at work and they also observe students' written and oral communications. "Intermediate students complete Concept Checks in which they explain their thinking as they solve problems after every few lessons" (Slavin & Madden, 2001, p. 205). At the end of each lesson students practice the skills learned to solve practical real-world situations and explain and communicate about their thinking. Communication is an important component of the MathWings program not only because it is one of the means students use to develop, explain, and defend their thinking, but it is also through these interactions that teachers are able to assess the students' mathematical understanding. Students are expected not only to solve mathematical problems, but they also need to write explanations of the processes through which they arrived at solutions. At the end of every lesson students write short entries in their logbooks in response to a written prompt about the lesson. These entries are another means of assessment.

Identification as Constructivist or Explicit Instruction approach

As explained earlier, MathWings was designed as a response to teachers' requests for a constructivist approach that includes materials, assessments, teachers' manuals, professional development, and other types of support. This program is based on the premise that students arrive at the school with a great amount of mathematical knowledge and they need instruction on how to express and formally represent that knowledge using mathematical symbols. MathWings helps students to transition from concrete mathematical understanding to pictorial representation to abstract mathematical thinking. These premises fall within the realm of a constructivist approach.

Classroom implementation and structure

MathWings is a very structured program that involves daily routines that support student learning and classroom management. Among these routines are "facts practice such as weekly timed facts tests to encourage mastery of basic facts and practice problems at varying difficulty levels to provide for fluency in the use of essential algorithms" (Slavin & Madden, 2001, p. 207). Intermediate MathWings daily lessons consists of three main components: Check-In, Action Math or Power Math, and Reflection. Daily lessons last an average of 60 to 75 minutes. Check-In, lasting approximately 15 minutes, is a time for team set-up. It is also a team routine dedicated to completing one challenging real-world problem and a team discussion of the various strategies to solve it. Check-In also includes a facts or fluency study process and brief review of homework.

Action Math Units and Power Math Units are the heart of the lesson which last 40-55 minutes and involve students in active instruction, teamwork, and assessment. Intermediate MathWings classes "intersperse 1-week to 2-week Power Math units among Action Math units" (Slavin & Madden, 2001, p. 209). Power Math units are lessons of individualized instruction in which students work on remediating gaps in prior skills and concepts, refining and mastering grade-level material, or accelerating their skills. During Power Math students work at their own pace and the teacher may teach a group of mix-ability students who need further instruction in specific skills (Madden et al., 1999; Slavin & Madden, 2001).

Action Math units are taught to the entire class.

When the class is doing an Action Math unit, the lesson involves the students in active instruction, teamwork, and assessment. During active instruction, the teacher and students interact to explore a concept and its practical applications and skills. The teacher may present a challenging problem for students to explore with manipulatives to construct a solution, challenge the teams to use prior knowledge to discover a solution, and ask the teams to find a pattern to develop a rule (Slavin & Madden, 2001, p. 209).

Teamwork and cooperative learning are evident when students are given a problem that they explore and solve as a team. Members of the team share with each other their understanding of the problem and come to consensus about how to solve it. The teacher chooses team members at random to share their ideas and solution with the class. Team members also check answers with each other. The last portion of the unit is an "assessment" in which one or more brief problems are used as a quick individual assessment of mastery of the concept or skill explored in the lesson (Slavin & Madden, 2001, p. 209).

Reflection time lasts approximately the last five minutes of the class. This activity involves the teacher providing a quick summary of the key concepts covered during the lesson. Homework sheets are passed out during this period, and students write a short entry into their Logbooks as a response to a teacher's prompt about the lesson.

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