Mathematics Intervention for First- and Second-Grade Students With Mathematics Difficulties

The Effects of Tier 2 Intervention Delivered as Booster Lessons

Diane Pedrotty Bryant
Brian R. Bryant
University of Texas at Austin

Russell Gersten
Instructional Research Group, Long Beach, California

Nancy Scammacca
University of Texas at Austin

Melissa M. Chavez
University of Texas Elementary School, Austin

This study sought to examine the effects of Tier 2 intervention in a multitiered model on the performance of first- and second-grade students who were identified as having mathematics difficulties. A regression discontinuity design was utilized. Participants included 126 (Tier 2, *n* = 26) first graders and 140 (Tier 2, *n* = 25) second graders. Tier 2 students received 15-min intervention booster lessons for 18 weeks in early mathematics skills and concepts. Results showed a significant intervention effect for second-grade Tier 2 students on the *Texas Early Mathematics Inventories–Progress Monitoring* (TEMI-PM) total standard score. The effect was not significant for first-grade Tier 2 students.

Keywords: *Tier 2 intervention; response-to-intervention; mathematics intervention; mathematics difficulties*

Preventing learning problems through the identification of students who are at risk for academic difficulties and providing evidence-based multitiered intervention at an early age are widely endorsed in reading and are gaining interest in mathematics (Chard et al., 2005; Fuchs et al., 2005; Fuchs & Fuchs, 2001; Gersten, Jordan, & Flojo, 2005; Vaughn & Fuchs, 2003). Briefly, Tier 1 consists of evidence-based core instruction for all students. Tier 2 includes supplemental intervention and ongoing progress monitoring for identified struggling students. Instructional delivery in Tier 2 is characterized by flexible groupings, informed instructional decision making, and evidence-based interventions. Tier 3 is reserved for those students who are struggling to the extent that they require intensive intervention, which might include additional instructional time, small instructional grouping, adapted instructional content, and different materials. In the area of early reading, a tiered-model approach to prevention and intervention has shown educational benefits (e.g., Vaughn, Linan-Thompson, & Hickman-Davis, 2003). Generalizing from early reading to mathematics, we can surmise that without early identification, intervention, and progress monitoring to determine students' response to intervention, many young students with mathematics difficulties may not develop a level of mathematics automaticity that is necessary for becoming proficient in mathematics.

There has been an increasing interest in early mathematics difficulties. We know that 5% to 10% of school-age children exhibit mathematics disabilities (Fuchs et al.,

2005; Fuchs, Fuchs, & Hollenbeck, 2007; Gross-Tsur, Manor, & Shalev, 1996; Lewis, Hitch, & Walker, 1994; Ostad, 1998) and that mathematics disabilities (i.e., in calculations and problem solving) are a recognized type of learning disability (Individuals with Disabilities Education Improvement Act of 2004). The growing body of research on young children's mathematics cognition has greatly contributed to our understanding of the early numeracy skills that prove problematic for students at risk for mathematics disabilities. To help prevent mathematics disabilities, it stands to reason that the research efforts in early reading can be replicated in early mathematics identification and intervention to prevent mathematics disabilities that result from inadequate instruction. However, there is a need for validated interventions to address early mathematics difficulties. We can draw from the research on the nature of mathematics difficulties to inform the development of appropriate interventions.

An Overview of the Nature of Mathematics Difficulties

In examining the nature of cognitive development related to mathematics difficulties of young students, researchers (e.g., Geary, 1990, 1993; Griffin, Case, & Siegler, 1994; Jordan, Kaplan, Oláh, & Locuniak, 2006) have studied the elements of *number sense*, which is defined as "moving from the initial development of basic counting techniques to more sophisticated understandings of the size of numbers, number relationships, patterns, operations, and place value" (National Council of Teachers of Mathematics [NCTM], 2000, p. 79). Jordan et al. (2006) identified key elements of number sense, which include counting (e.g., cardinality and stable order principles), number knowledge (e.g., quantity discrimination, counting sequences), number transformation (e.g., addition and subtraction, verbal and nonverbal calculations), and estimation (e.g., of group size). An understanding of how young students at risk for mathematics disabilities perform on these elements compared to typically achieving students can inform mathematics intervention for prevention and remediation.

Research has been conducted to identify the predictive variables of mathematics difficulties (Fuchs et al., 2005; Geary, 1990; Geary, Hamson, & Hoard, 2000; Jordan et al., 2006; Jordan, Hanich, & Kaplan, 2003). Overall, findings have shown that cognitive development problems are manifested in difficulties with understanding number knowledge and relationships (e.g., magnitude, sequencing, base 10), solving word problems, and using efficient counting and calculation strategies (e.g., counting on, doubles + 1) to solve arithmetic combinations (i.e., number facts). Findings

from studies in these areas informed the design of the preventative intervention practices described in this article, specifically, in the area of number knowledge and relationships and arithmetic combinations.

Number Knowledge and Relationships

Key early indicators are discerning magnitude of numbers, understanding the base-10 system, and computing mental calculations (Gersten & Chard, 1999; Jordan et al., 2006). Jordan et al. (2006) found that at the end of kindergarten, there existed a group of students whose response to typical kindergarten instruction was identified as low and flat, suggesting that going into first grade, these students would require an intervention to prevent further instructional delay.

The base-10 system (i.e., place value, computation) arguably is one of the most important concepts students must fully grasp (Van de Walle, 2004). Place-value understanding helps students conceptualize numerical relationships and the *how* and *why* of computational procedures. Unfortunately, limited core mathematics instructional time is devoted to teaching and practicing base-10 concepts (Bryant, Smith, & Bryant, 2008). As a result, research results suggest that young students demonstrate problems in the area of place-value tasks.

For example, Jordan et al. (2003) conducted a longitudinal study of 180 students in second grade and followed them to third grade. They were administered a battery of tests designed to assess performance on a variety of early mathematics tasks that included place value. Place-value tasks involved problems with standard (e.g., 43 = four 10s and three 1s) and nonstandard (e.g., 43 = three 10s and thirteen 1s) place-value and digit representations (e.g., 43: Show with concrete models what 4 stands for; count out 40 chips). Jordan et al. found that after time, students with mathematics difficulties scored lower on place-value tasks compared to average students. These findings suggest that students with mathematics difficulties require sustained instructional time in place-value concepts in the early grades.

Arithmetic Combinations

Researchers (e.g., Geary, 1990, 2004; Jordan et al., 2003) have found that persistent deficits in the retrieval of arithmetic combinations among elementary-age students are associated with mathematics difficulties. These students typically display difficulties in mastering arithmetic combinations because of immature counting strategies (e.g., counting all, counting on fingers), which contribute to difficulties in developing computational fluency. It appears, then, that difficulties with arithmetic combinations are a defining feature

of students with mathematics difficulties (Gersten et al., 2005; Hanich, Jordan, Kaplan, & Dick, 2001; Jordan, Kaplan, & Hanich, 2002) and are an important contributor to students' ability to solve whole-number computation and word problems (Fuchs et al., 2005). If we surmise that the use of mature and efficient counting strategies contributes to the development of computational fluency, then we can hypothesize that teaching effective strategies to enhance mastery and fluency of arithmetic combinations should be part of an intervention for students at risk for mathematics disabilities.

In sum, overall findings from research on predictors of mathematics difficulties of young students are beginning to contribute to the development of early mathematics intervention. We know that many students demonstrate problems with number-sense tasks, arithmetic combinations, and word problems (Fuchs et al., 2005; Fuchs & Fuchs, 2005). Overall research findings have shown that generally, students with mathematics difficulties demonstrate developmentally different characteristics that remain persistent across the grades (Geary, 1993; Jordan et al., 2002). Continued longitudinal studies on the predictive nature of number-sense tasks and other mathematics skills and concepts (e.g., algebra, measurement, geometry) on the mathematics achievement of at-risk students may offer implications for early intervention development.

Early Mathematics Intervention

Compared to early reading intervention research, there is a paucity of research on early (first- and second-grade) Tier 2 intervention to prevent mathematics disabilities in struggling students and to address the difficulties young students are experiencing in mathematics instruction (Gersten et al., 2005). The majority of mathematics studies that are available focuses on research for older students with math disabilities or low achievement (e.g., Fuchs et al., 2003).

A few studies were identified that conducted whole-class instruction, typically Tier 1 instruction with younger students. For example, whole-class intervention programs, such as Number Worlds (Griffin et al., 1994) and Peer Assisted Learning Strategies (Fuchs, Fuchs, & Karns, 2001; Fuchs, Fuchs, Yazdian, & Powell, 2002), provide effective practices for teaching numeracy skills to low-achieving students.

Additionally, Fuchs et al. (2006) conducted a pilot study on instruction within the context of the general education classroom (student pairs or whole class in a computer lab). The study focused on the effects of computer-assisted instruction (CAI) on the acquisition and transfer of number combination (i.e., addition and subtraction facts with sums or minuends to 18) of 16 first-grade students with concurrent risk for mathematics and reading difficulties. CAI was employed in 10-min sessions for a total of 50 sessions (average 46.44, $SD = 2.76$, sessions for mathematics) across 18 weeks. Findings showed that students benefited from CAI when learning addition combinations but that similar benefits were not demonstrated for subtraction combinations. Importantly, effects did not transfer (generalize) to students' accuracy in solving word problems. The authors recommended conducting additional research with a larger sample, increasing the number of weekly sessions, incorporating pictorial representations into the CAI program, and providing more follow-up tasks to facilitate transfer.

Although the number of studies is limited, research findings and intervention syntheses (e.g., Baker, Gersten, & Lee, 2002; Kroesbergen & Van Luit, 2003; Swanson, Hoskyn, & Lee, 1999) offer insight into practices and materials that hold promise for teaching young students who struggle with early mathematics. Researchers have offered recommendations for prevention and intervention, including peer-assisted tutors (Baker et al., 2002; Fuchs et al., 2001), verbalizations of cognitive strategies (Fuchs & Fuchs, 2001), and physical (concrete) and visual (pictorial) representations of number concepts (Fuchs et al., 2001; Gersten et al., 2005). Findings from studies on students with mathematics difficulties support the use of explicit, strategic instruction in teaching procedural and conceptual concepts (e.g., calculations principles, commutative property of addition, counting strategies; Baker et al., 2002; Butler, Miller, Crehan, Babbit, & Pierce, 2003; Gersten et al., 2005; Swanson et al., 1999).

Explicit and Strategic Instruction

Swanson et al. (1999), in their meta-analysis on academic treatment outcome for students with learning disabilities, found that studies that used explicit and strategic instructional procedures had larger effect sizes compared to other instructional approaches. Instructional procedures include sequencing instruction, providing instructional routines (e.g., presentation of subject matter, guided practice, and independent practice), focusing on massed practice, teaching to criterion, and evaluating student learning on a regular basis (Swanson, 2001). Small-group instruction is also recommended as an effective grouping practice to provide multiple opportunities for students to practice and receive immediate corrective or positive feedback from the teacher (Vaughn, Moody, & Schumm, 1998). Research findings on the benefits of explicit, strategic instructional procedures are

Table 1
Demographic Information for At-Risk and Not-At-Risk First- and
Second-Grade Participants (in percentages)

	Number of Participants by Grade			
	Grade 1		Grade 2	
Variable	At Risk $n = 26$	Not At Risk $n = 100$	At Risk $n = 25$	Not At Risk $n = 115$
Gender				
Male	54	52	62	56
Female	46	48	38	44
Race				
African American	17	26	37	27
Hispanic	40	28	7	39
White	34	34	44	25
Asian/Pacific Islander	09	11	11	9
Qualified for free or reduced lunch				
Yes	37	33	37	42
No	63	67	63	58

well documented in the mathematics disability literature (Baker et al., 2002; Butler et al., 2003; Gersten et al., 2005; Swanson et al., 1999). It stands to reason that these same procedures can be employed with young students who are identified as at risk for mathematics disabilities. Equally important is the instructional content.

Early Intervention Instructional Content

In thinking about mathematics skills and concepts to target for early intervention, we must be mindful of findings from predictive studies about the mathematics characteristics of young, struggling students (e.g., difficulties with number-sense tasks and arithmetic combinations). We based our intervention work on the early numeracy literature (e.g., Jordan et al., 2003, 2006) that describes skills that are problematic for students with mathematics difficulties.

Clements and Sarama (2004) suggest that on the basis of the NCTM's (2000) *Principles and Standards for School Mathematics*, "number and operations is arguably the most important of the area" (p. 16). Thus, we chose to focus our Tier 2 intervention on specific skills and concepts taken from the Number, Operation, and Quantitative Reasoning Skills and Concepts standard for Grades K–2 (refer to www.nctm.org for a description of the standards and to www.nctm.org/focal-points/downloads.asp for the NCTM curricula focal points). We chose Tier 2 as our focus rather than Tier 3, because the intent is to identify students who are demonstrating mathematics difficulties and to provide intervention to prevent future learning difficulties.

We know a great deal about effective instructional procedures for teaching struggling students, and there is compelling evidence to focus on foundation skills in early mathematics instruction at the primary level. The emerging database about early mathematics intervention is promising but remains limited in scope compared to the availability of research-validated early reading intervention. Thus, there is a need for studies to validate early mathematics Tier 2 intervention for students at risk for mathematics disabilities. The purpose of this study was to determine the effects of Tier 2 intervention on the number, operation, and quantitative reasoning performance of students in first and second grades who were identified as having mathematics difficulties.

Method

Participants

This study took place in a primary-level elementary school in a major suburban school district in central Texas. The primary elementary school serves students in Grade Pre-K through second grade. Participants in this study included 126 students in first grade and 140 students in second grade who had returned parent or guardian permission slips and participated in pre- and posttest assessments.

The school district provided demographic characteristics of the sample with regard to key variables (see Table 1). Only students who spoke and understood English participated in this study, but the school-reported demographics showed that only 8% of the student body (Grades

K–2) were English learners (individual data on this characteristic were not available from the district).

Design

The effects of early intervention were assessed using the regression-discontinuity design (RD). This quasi-experimental design is a particularly strong alternative to a randomized experiment when the goal is to evaluate the efficacy of a program (Shadish, Cook, & Campbell, 2002; Trochim, 1984). It is appropriate to use RD when the group receiving intervention and the control group are purposely selected to differ in preintervention ability as assessed by a quantitative measure prior to the introduction of the intervention. The key to a successful RD is that the researchers enforce the cutoff criterion strictly. When this is done, RD provides a robust alternative to a randomized experimental design, with the added benefit of not having to construct a control group by denying the intervention to those who need it. The likelihood of extraneous variables causing any observed effect is miniscule if a strict quantitative criterion is used to assign students to intervention and control conditions.

The underlying assumption behind RD is that if there were no treatment effect, the relationship between the pretest criterion score (used to select students for intervention) and the posttest outcome score would be the same for all students (those who did and those who did not qualify for intervention). In other words, the null hypothesis is that the regression line for pretest and posttest scores for the students who scored above the cutoff (and received no intervention) would accurately predict posttest scores for students who did receive the intervention (i.e., scored below the cutoff). An effective intervention would significantly raise the scores of students who scored below the cutoff. Data analysis examines the degree to which the actual regression line for the students who received intervention differs from the expected line and determines whether this is likely to be due to chance or a systematic increase above projected scores. A statistically significant discontinuity between these two regression lines indicates that the intervention had a significant effect.

RD can be used to determine both main effects and interactions between pretest score and treatment. An interaction effect indicates whether the intervention is particularly effective with a subgroup of the students who received intervention (typically, those who score highest or lowest on the pretest).

The students were administered the four subtests composing the *Texas Early Mathematics Inventory–Progress Monitoring* (TEMI-PM), described in the Measures section. Although different methods and cut scores have been used to identify mathematics difficulties (e.g., Geary, 1990; Hanich et al., 2001; Parmar, Cawley, & Frazita, 1996), for the purposes of this study, students who scored at or below the 25th percentile (total standard score of 90 or below) at the start of the school year on the TEMI-PM were assigned to the Tier 2 treatment group. Students who scored above 90 on the TEMI-PM at the start of the school year received no intervention but did take the TEMI-PM posttest measure at the same time as the intervention students.

Measures

During the academic year 2005–2006, all participating students were administered a set of researcher-designed experimental mathematics measures, the *Texas Early Mathematics Inventories–Progress Monitoring*, in the fall (September), winter (January), and spring (late April–early May). The mathematics subtests from the *Stanford Achievement Test–10th Edition* (SAT-10; Harcourt Assessment, 2003) were also administered in the spring of 2006. First graders were administered the Primary I level, consisting of Mathematics Procedures (MP) and Mathematics Problem Solving (MPS). Mathematics Procedures consists of addition and subtraction items. Mathematics Problem Solving is composed of items that assess a variety of mathematics skills (e.g., numeration, operations, word problems, statistics, and probability). A Total Mathematics score (TMS) is also available. For second grade, the Primary 2 is administered; the same scores are available as for the Primary I level. The SAT-10 internal consistency reliability coefficients for our sample were computed using the coefficient alpha technique (first grade MP $= .85$, MPS $= .87$, TMS $= .92$; second grade MP $= .89$, MPS $= .88$, TMS $= .93$). Concurrent validity of the TEMI-PM scores was assessed by correlations with the SAT-10 and is reported by subtest.

The TEMI-PM consists of four forms (A, B, C, D); only Form A was administered in both fall and spring. There are four subtests: Magnitude Comparison (MC), Number Sequences (NS), Place Value (PV), and Addition/Subtraction Combinations (ASC). An aggregate total score of the four subtests was used to measure pre- and posttest student performance in the RD analysis because it is the most robust indicator of performance of the four constructs (B. R. Bryant et al., 2007). Descriptions of the TEMI-PM subtests and the total score are provided below. Included at the end of each test description are data concerning reliability and validity. These data provide beginning evidence for the construct validity of the TEMI-PM scores reported in this study.

Magnitude Comparison. This subtest assesses a child's ability to differentiate the bigger or smaller of two numbers that are shown side by side within a box. The measure is similar to that used by Clarke and Shinn (2004) and Chard et al. (2005) in their Quantity Discrimination measure.

For first-grade students, MC is individually administered. Targeted numerals range from 0 through 99; students are told to name the smaller of the two numbers. If two numbers are equal (e.g., 35, 35), they are told to say *equal*.

For second-grade students, the test is group administered. Targeted numerals range from 0 through 999, and students identify which of the two numbers is "less" by circling their answer (i.e., the smaller number) on the stimulus sheet. If two numbers are of equal magnitude, students draw a circle around both numbers. The use of the word *less* is designed to match vocabulary that should have been mastered by the end of the first grade. The students state or circle their answer within each two-numeral set in left-to-right order for 1 min, and the amount of correctly identified numbers constitutes the raw score.

Immediate test–retest with alternate-forms reliability coefficients for Form A with Forms B, C, and D ranged from .88 to .90 (median = .88) for first grade and from .80 to .87 (median = .86) for second grade. Correlating the spring Form A MC score with the Total Mathematics score from the SAT-10 yielded a concurrent validity coefficient of .63 for first grade and .49 for second grade.

Number Sequences. This experimental measure assesses a child's ability to identify a missing number from a sequence of three numbers. The missing number could appear in any of three positions: the first number, the second number, or the third number. This measure is adapted from one Clark and Shinn (2004) used in their Missing Number Varied 1-20 test.

For first-grade students, targeted numerals ranged from 0 through 99; for second-grade students, targeted numerals ranged from 0 through 999. Two different numerals and one blank (the missing number was represented by a blank) constitute a set and appear in boxed rows of a student stimulus worksheet, several boxed sets to a row. The first-grade children name the missing number during individual administration; they have 1 min to do as many items as they can, and the amount of correctly identified missing numbers is summed to constitute the raw score.

For second graders, NS is group administered; students write the missing number in the blank that substitutes for the missing number in the series. The amount of correctly written missing numbers obtained in 1 min is summed to compute the raw score. Immediate test–retest with alternate-forms reliability coefficients for Form A with Forms B, C, and D ranged from .88 to .90 (median = .89) for first grade

and from .74 to .88 (median = .78) for second grade. Spring intercorrelations between Form A NS scores and SAT-10 Total Mathematics score resulted in concurrent validity coefficients of .58 for first grade and .60 for second grade.

Place Value. This experimental test is designed to assess first and second graders' knowledge of place value. The test uses a similar format to what is commonly seen in early mathematics textbooks (e.g., Charles et al., 1999: Scott Foresman—AddisonWesley; Bell et al., 2001: SRA/McGraw-Hill). For first graders, values range from 1 to 99. For second graders, values range from 1 to 999.

Students in first grade are shown boxes of figures depicting 10s and 1s during individual administration. For example, the number 34 is depicted by showing three groups of 10s and four 1s. The student provides an oral response stating how many there are in all. A 1-min time limit is imposed.

Students in the second grade see boxes of figures depicting 100s, 10s, and 1s. For example, the number 134 is depicted by showing one group of 100, three groups of 10s, and four 1s. The student has to write the quantity shown (i.e., how many), in this case, 134.

Intercorrelation coefficients between Form A and Forms B, C, and D ranged from .81 to .85 (median = .83) for first graders and from .71 to .78 (median = .72) for second graders. Correlating Form A with the Total Mathematics score from the SAT-10 yielded a validity coefficient of .64 for first grade and .63 for second grade.

Addition/Subtraction Combinations. This experimental measure assesses first and second graders' ability to correctly write the answers to addition and subtraction facts (sums or minuends ranging from 0 to 18). Items appear eight to a row, with five rows of problems in all. Students in both grades compute and write their answers to as many items as they can in 1 min. The total number of correctly computed problems written correctly (e.g., with no reversals or gross illegibility) is summed to produce the raw score. Immediate test–retest with alternate-forms reliability coefficients for Form A with Forms B, C, and D ranged from .72 to .93 (median = .83) for first graders and from .72 to .84 (median = .83) for students in second grade. We correlated the results of Form A ASC with the Total Mathematics score from the SAT-10, which resulted in a validity coefficient of .55 for first grade and .59 for second grade.

Total score (TOT). Local normative scores (standard scores having a mean of 10 and standard deviation of 3) were computed at each grade level. Total scores were derived using the sum-of-standard-scores procedure,

wherein the standard scores for MC, NS, PV, and ASC were summed and the results across students averaged to generate a total standard score having a mean of 100 and standard deviation of 15. Using the median reliability coefficients for MC, NS, PV, and ASC, we used Guilford's (1954) formula to compute a reliability coefficient for the first-grade and second-grade composite. The resulting reliability coefficients for the Total scores for first and second grades, respectively, were .95 and .92. We also correlated the spring Form A TOT with the Total Mathematics score of the SAT-10; the resulting concurrent validity coefficient for first grade was .72 and for second grade was .73.

Data Collection Procedures

For group testing, project staff administered the tests to intact classrooms of students who had returned signed, affirmative permission slips. A testing monitor was also present during testing to help keep students on task, and classroom teachers were asked to remain in the room for behavior-management purposes. For individual testing, examiners were given a class list to share. For both grade levels, timers were used to ensure accuracy in the amount of time allotted for testing.

Training. A 3-hr training session occurred in late summer 2005, with refresher training conducted prior to each test administration. A training session on all measures was conducted for the project testers, who were either undergraduate or graduate students in general education, special education, or educational psychology. All students had taken a basic assessment course. During training, administration and scoring procedures for each of the experimental tests and the SAT-10 were explained and modeled. Project staff served as test administrator and "student," providing examples of effective test administration. Following modeling, questions were posed and answered; then the prospective testers were provided scripted tests to practice giving the tests to one another and recording item responses. Testers were observed and monitored while administering and scoring the practice items. The process continued until prospective testers responded to the testing situation with 95% agreement and accuracy.

Examiner fidelity. To ensure fidelity of administration and scoring in first grade, examiners were observed by one of three members of the project staff. Each project staff member observed a student being evaluated and scored the student's performance on a second protocol. Before evaluating interscorer reliability between a tester and the primary tester, the rating consistency among the project staff members was computed, and agreement was found to be better than 97%.

For first-grade testing, reliability checks occurred for more than 20% of each grade's data on each test. The raters achieved more than 97% agreement across all the measures during each testing period (fall, winter, spring). The second raters checked all testers at least three times. The ratings were conducted across 4 days during each testing period. Interrater reliability was calculated by dividing the number of agreements by the total number of student trials and multiplying the quotient by 100. Results for the fall indicated a range of agreement from 96.2% to 100% (median $= 98.7\%$) for the fall testing, from 97.7% to 100% (median $= 99.0\%$) for winter testing, and from 98.6% to 100% (median $= 99.5\%$) for spring testing.

Fidelity for second-grade testing and SAT-10 testing (all grades) was examined differently because all measures were group administered. Trained examiners read aloud the group-administration instructions to the students while an additional trained examiner served as monitor. In this role, the monitor was directed to stop the examiner if any instructions were conveyed incorrectly and to report any discrepancies during testing to the site assessment coordinator. The monitors reported successful implementation of the test instructions.

Intervention

Tutoring sessions were delivered in same-ability, small instructional groups consisting of three to four students within a grade level (first or second grade) from across classes. Taking absences into consideration, a median of 64 fifteen-min tutoring sessions for first graders and a median of 62 fifteen-min tutoring sessions for second graders were conducted across 18 weeks.

Four tutors were identified to conduct the Tier 2 intervention booster lessons. One full-time tutor and three graduate research assistants (GRAs) were trained by the first author to implement the lessons. The full-time tutor was a former kindergarten teacher with 17 years of classroom experience. Two of the GRAs were full-time doctoral students in the Department of Education Psychology, and one was a full-time doctoral student in the School of Social Work; they all tutored for the project 20 hr per week. The GRAs had previous teaching or tutoring experience.

Tutor training. At the beginning of the program, initial training consisted of (a) an explanation of the program, (b) a description of the lessons, and (c) an explanation of procedures for explicit, systematic instruction. Tutors were given time to practice the initial lessons. Once the program began, additional tutor training consisted of reviewing new

Table 2
Conceptual Framework for First- and Second-Grade Number, Operation, and Quantitative Reasoning

Number concepts
    Counting: rote, rational, counting up or back, skip (2, 5, 10)
    Number recognition and writing: 0–99 (first grade); 0–999 (second grade)
    Comparing and grouping numbers: number relationships of more, less; relationships of one and two more than or less than, anchoring numbers to 5 and 10 frames; part-part-whole relationships (e.g., ways to represent numbers)
    Numeric sequencing
Base 10 and place value
    Making and counting: groups of 10s and 1s (first grade); groups of 100s, 10s, and 1s (second grade)
    Using base-10 language (three 100s, zero 10s, six 1s) and standard language (306) to describe place value
    Reading and writing numbers to represent base-10 models
    Naming the place value held by digits in numbers
Addition and subtraction combinations
    Identity element and properties
    Fact families
    Counting and decomposition strategies (e.g., addition: count on [+ 0, + 1, + 2], doubles, doubles +1, make 10 + more; subtraction: count down [–0, –1, –2, –3], count up; number bonds)

lessons and making adjustments to lessons based on tutors' feedback.

Tutoring program. The focus of this Tier 2 intervention program was on the development and implementation of booster lessons. The intent was to "boost" student learning in the area of number, operation, and quantitative reasoning by providing systematic, explicit intervention in small groups during the school day. These lessons composed Tier 2 intervention and were supplemental to core mathematics instruction, which ranged from 45 min to 60 min of instruction on the designated skill areas (e.g., measurement, problem solving) for the week. Content for the booster lessons was based on the number, operation, and quantitative-reasoning skills and concepts from the Texas Essential Knowledge and Skills (TEKS) standards. The mathematics TEKS are rooted in the *Principles and Standards for School Mathematics* from the National Council of Teachers of Mathematics (2000). Table 2 shows the conceptual framework used to guide the development of booster lessons.

The booster lessons were designed on the basis of practices identified as critical for students who are at risk for or have identified mathematics difficulties with the following features. First, a combined instructional approach employing explicit, systematic teaching procedures and strategic

instruction was implemented. Procedures including modeling, "thinking aloud," guided practice, pacing, and error correction were used to deliver the scripted booster lessons. During modeling, tutors demonstrated the processes or steps needed to solve problems or provided explanations of how to perform skills. Strategic instruction focused on teaching students specific strategies for learning addition and subtraction combinations. Guided practice activities consisted of multiple opportunities to practice skills and concepts including reading, writing, and "making" numbers within a given number range (described below).

Second, the instructional content was controlled during a 2-week instructional time period. Within an instructional 2-week time period, booster lessons were provided on skills and concepts related to number concepts, base 10 and place value, and addition and subtraction combinations. Particularly, emphasis was placed on those number concepts that prove problematic for students with mathematics difficulties (e.g., teen numbers, zero as a place holder). Also, within each 2-week time period, a designated number range was targeted that represented a smaller unit of the identified number range for that grade level. For example, numbers 0 through 99 were taught in first grade, so a unit of instructional content for first grade for a 2-week period might include numbers 10 through 20. For second grade, numbers 0 through 999 composed the curriculum; the instructional number range for a 2-week period might include numbers 100 through 200. Instructional content for the 2-week booster lessons, then, focused on the designated number range across lessons that dealt with number concepts and relationships (i.e., magnitude, number identification and writing, numeric sequencing and counting), base 10, and place value. Instructional content for addition and subtraction combinations included sums or minuends ranging from 0 to 18 and sequenced from easier (e.g., addition facts + 0, + 1, + 2; subtraction facts − n, − 0, − 1) to more difficult (e.g., addition facts doubles + 1 [6 + 7], make 10 + more [9 + 7]; subtraction inverse facts) combinations. Addition and subtraction combinations were taught separately, with the easier combinations for both preceding the more difficult ones.

Third, as appropriate, the concrete–semiconcrete–abstract (CSA) approach (Butler et al., 2003; Mercer, Jordan, & Miller, 1996) was used to teach number concept and relationships, base 10 and place value, and addition and subtraction combinations. We used a variety of instructional materials with this approach. For example, at the concrete level, base-10 models and counters were used to teach concepts and skills. For the semiconcrete level, we used number lines and 100s charts. Finally, the abstract level focused on the manipulation of numerals. Also, the levels were mixed so that students might manipulate base-10

models to make numbers, read numbers, and write numbers of concrete model representations.

Finally, daily activity-level progress monitoring was conducted. Students were given four either oral or written problems to determine their response to instruction on each booster lesson taught that day. The majority of students in the group had to demonstrate accuracy on three out of four of the problems to consider the lessons as successful for each day.
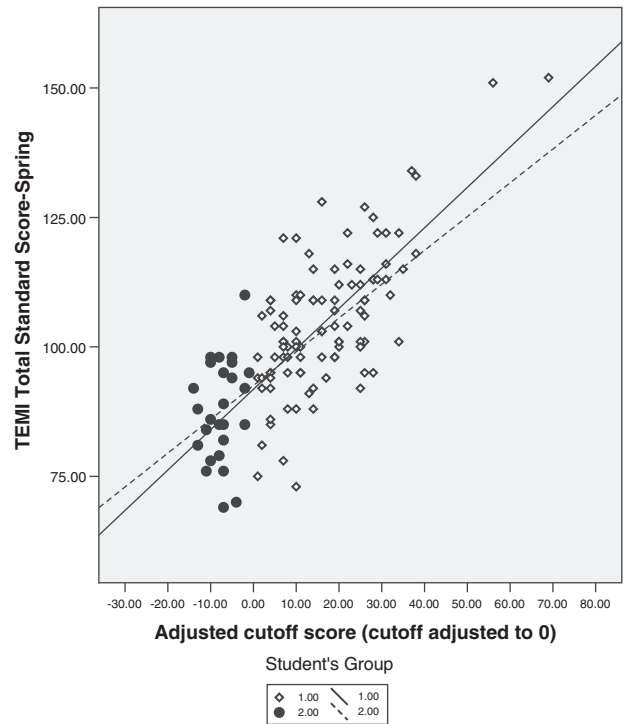
Fidelity of Implementation

An expert trainer (project coordinator) observed treatment sessions for each tutor for three sessions for the 18-week intervention to assess fidelity or quality of implementation of specific performance indicators. Quality performance indicators included (a) following the scripted lessons for the content, (b) implementing the instructional procedures, and (c) managing student behavior and materials. Performance indicators were rated on a 0- to 2-point scale where 0 = *indicator not implemented*, 1 = *indicator implemented on a limited basis*, and 2 = *indicator implemented on a regular basis*. Results were shared with the tutors, and areas in need of further training were addressed. Results on the quality performance indicators showed (a) for following the scripted lessons for the content, a median of 1.83 with a range of 1.66 to 2.00; (b) for implementing the instructional procedures, a median of 2.00 with a range of 1.86 to 2.00; and (c) for managing student behavior, a median of 2.0. These results across both grades show that across the tutors overall, there was a high degree of fidelity in the implementation of the booster lessons.

Results

First Grade

Complete pretest and posttest data were available for 100 students who did not qualify for intervention and did not receive intervention and for 26 students who qualified for and received intervention. For the spring (posttest) TEMI-PM total standard score, RD analysis revealed that no significant effect was observed among first-grade students ($b = .04$). Figure 1 shows a scatter plot of scores and regression lines for Tier 1 and Tier 2 students. On the plot, the cutoff score has been adjusted to zero (by subtracting 90 from each student's pretest score) to better depict the data. Note that at zero on the x-axis, there is little to no discontinuity between the regression line for the Tier 2 (at-risk) group and the Tier 1 (not-at-risk) group.

Figure 1
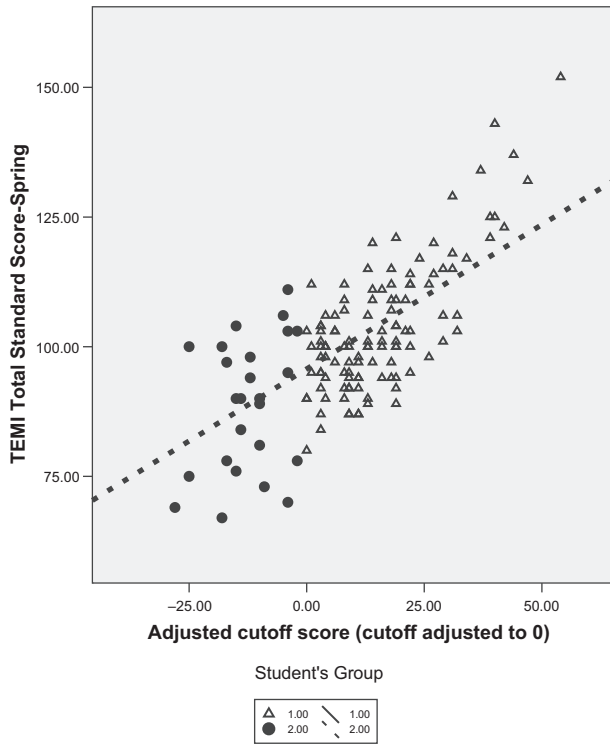**Scatter Plot of Grade 1 Scores**
With Regression Lines

Note: TEMI = *Texas Early Mathematics Inventories*.

Second Grade

Complete pretest and posttest data were available for 115 students who did not qualify for intervention and did not receive intervention and for 25 students who qualified for and received intervention. The RD analysis showed that a significant main effect ($b = .19, p = .018$) was observed for the spring TEMI-PM total standard score, indicating a positive effect for the intervention with second-grade students.

Figure 2 shows a scatter plot of scores and regression lines for Tier 1 and Tier 2 students. At zero on the x-axis, there is a discontinuity (a gap) between the regression line for the Tier 2 (at-risk) group and the Tier 1 (not-at-risk) group. This discontinuity demonstrates the positive effect of the program on Grade 2 at-risk students. If at-risk students had not received intervention, it is expected that their posttest scores would be equal to the values on the regression line for the not-at-risk students at zero on the x-axis and to the left of zero (because zero is the cutoff point for selection for intervention, all at-risk students have scores that fall at zero or below on the x-axis). Because the regression line for the actual

**Figure 2
Scatter Plot of Grade 2 Scores With
Regression Lines**

Note: TEMI = *Texas Early Mathematics Inventories.*

posttest scores for at-risk students is above the regression line for not-at-risk students at zero on the x-axis and to the left of zero, we conclude that the posttest scores of at-risk students were significantly higher than expected, resulting in the finding of a main effect for the intervention.

Regression discontinuity analyses at the subtest level indicated that a significant main effect existed for the Addition/Subtraction subtest ($b = .21, p < .05$), whereas results for the remaining three subtests showed no significant effects.

Our finding is similar to other studies (e.g., Fuchs et al., 2005) showing that although Tier 2 intervention (tutoring) can improve mathematics achievement, especially for second graders in our sample, students' performance still remains below that of their typically achieving peers. Thus, identifying more powerful interventions is necessary to help close the performance gap between typically performing and Tier 2 students.

Discussion

Increasing attention is being focused on the identification of young students with mathematics difficulties. Research to

validate early mathematics Tier 2 interventions is important, because multitiered instruction is based on the premise that evidence-based interventions are being provided to prevent mathematics disabilities. We know a great deal about what constitutes effective instructional procedures (e.g., modeling, strategic instruction) that produce positive academic outcomes for struggling students (Swanson et al., 1999). These instructional procedures should be incorporated into mathematics intervention. Furthermore, a case can be made that Tier 2 intervention content should focus on mathematics skills such as number, operation, and quantitative reasoning because they are predictive of mathematics problems (Jordan et al., 2002, 2003). Thus, the purpose of this study was to determine the effects of Tier 2 intervention on the number, operation, and quantitative-reasoning performance of students in first and second grades who were identified as having mathematics difficulties. The TEMI-PM total score, which comprised four subtests, was used to identify (performing at or below the 25th percentile; TEMI-PM total standard score of 90 or below) students who were struggling in critical early mathematics skills and to monitor their progress during Tier 2 intervention.

A total of 26 first-grade and 25 second-grade students participated in the Tier 2 intervention delivered as booster lessons. Fifteen-min intervention sessions were conducted 3 to 4 days per week for 18 weeks. Students received instruction in small groups by trained tutors. The intervention consisted of explicit, strategic instructional procedures; instructional content (e.g., numbers 0–99 for first grade) for the designated grade level (first or second); and booster lessons in number concepts, base 10 and place value, and addition and subtraction combinations with sums or minuends to 18, respectively.

Findings showed differential effects by grade level. For first-grade Tier 2 students, the regression discontinuity analysis did not reveal a program effect, whereas for second-grade Tier 2 students, RD analyses showed a significant main effect, indicating a positive program effect. In attempting to explain the differential effects, it is possible that first graders need more intervention time to learn number-sense tasks. In particular, the teen numbers and 11 and 12 are often troublesome for struggling students to name. Numerical concepts (e.g., quantity discrimination, number sequences) and place value also require sustained instructional time that may not have been sufficient in our 15-min sessions. Also, arithmetic combinations (e.g., fact families, sums or minuends to 18), especially subtraction, take time to develop accuracy as well as fluency (Fuchs et al., 2006).

On the other hand, findings from second grade are encouraging regarding Tier 2 students' ability to improve their performance with number-sense tasks, place value, and

arithmetic combinations. Lessons specifically on number-sense tasks (e.g., number concepts) and fluency building with arithmetic combinations apparently provided students the added "boost" they needed to become more proficient in these areas. However, refinement of the booster lessons is needed to help close the achievement gap. Thus, future studies should examine additional tutoring features to help Tier 2 students achieve more commensurate with their peers.

The limitations of this study should be addressed in future research. Methodologically, a larger sample size is needed, and student performance on individual subtests should be examined. Also, instructional content should encompass word problem solving, given the issues students with mathematics difficulties manifest in this area (Fuchs & Fuchs, 2005; Jordan et al., 2003).

Future studies are warranted to strengthen the effects of the intervention for both first- and second-grade Tier 2 intervention. First, additional intervention time may be needed to allow students more practice opportunities with different representations (e.g., pictorial, abstract) and to provide more fluency-building time, especially with arithmetic combinations. This proposed change is in line with findings from other research. For example, Fuchs et al. (2006) recommend increasing the number of weekly intervention sessions, which was described in their original study as 18 weeks of CAI intervention. We would suggest increasing the number of sessions and the amount of daily intervention time to 20 min. Given that multiple tasks are taught, increasing daily time from 15- to 20-min sessions could provide more meaningful practice time that Tier 2 students require but oftentimes do not receive as part of Tier 1 teaching. Second, instruction in word problem solving is imperative. In our study, we chose to limit the number of skills because of the need to develop multiple booster lessons. However, instruction in the components of word problem solving (e.g., types of problems, extraneous information, multiple steps, contextualized problems) and near and far transfer, which is difficult to effect among struggling students, is especially important for struggling students (D. P. Bryant, Bryant, & Hammill, 2000; Fuchs & Fuchs, 2005; Woodward & Baxter, 1997). Finally, future research must examine the identification of Tier 3 students and specific, individualized interventions to address their learning needs. In reviewing the RD data in Figures 1 and 2, clearly there is a group of students whose performance remained low compared to other Tier 2 students.

In sum, Tier 2 intervention for students with mathematics difficulties holds promise for improving mathematics performance in number-sense tasks and arithmetic combinations. Practitioners can implement small-group intervention focusing on number, operation, and quantitative reasoning tasks with some assurance that a group of their struggling students will benefit from this instruction. Finally, instruction that includes explicit, strategic procedures along with materials that engage students in representing numerical concepts, place value, and arithmetic combinations should be included as part of Tier 2 intervention.

References

Baker, S., Gersten, R., & Lee, D. (2002). A synthesis of empirical research on teaching mathematics to low-achieving students. *The Elementary School Journal*, *103*, 51–73.

Bell, M., Bell, J., Bretzlaugh, J., Dillard, A., Hartfield, R., Isaacs, A., McBride, J., Pitvorec, K., & Saecker, P. (2001). *Everday mathematics: The University of Chicago School mathematics project*. Chicago, IL: SRA/McGraw-Hill.

Bryant, B. R., Bryant, D. P., Gersten, R., Roberts, G., Wagner, R., Kim, S. A., Seo, Y.-J., & Shih, M. (2007). *The development of early mathematics measures for identification and progress monitoring purposes*. Manuscript in preparation.

Bryant, D. P., Bryant, B. R., & Hammill, D. D. (2000). Characteristic behaviors of students with learning disabilities who have teacher-identified math weaknesses. *Journal of Learning Disabilities*, *33*(2), 168–177, 199.

Bryant, D. P., Smith, D. D., & Bryant, B. R. (2008). *Teaching students with special needs in inclusive classrooms*. Boston: Allyn & Bacon.

Butler, F. M., Miller, S. P., Crehan, K., Babbit, B., & Pierce, T. (2003). Fraction instruction for students with mathematics disabilities: Comparing two teaching sequences. *Learning Disabilities Research and Practice*, *18*, 99–111.

Chard, D. J., Clarke, B., Baker, S., Otterstedt, J., Braun, D., & Katz, R. (2005). Using measures of number sense to screen for difficulties in mathematics: Preliminary findings. *Assessment for Effective Intervention*, *30*(2), 3–14.

Charles, R. I., Chancellor, D., Moore, D., Schielack, J. F., Van de Walle, J., et al. (1999). *Math*. Menlo Park, CA: Scott Foresman—Addison Wesley.

Clarke, B., & Shinn, M. R. (2004). A preliminary investigation into the identification and development of early mathematics curriculum-based measurement. *School Psychology Review*, *33*(2), 234–238.

Clements, D. H., & Sarama, J. (Eds.). (2004). *Engaging young children in mathematics standards for early childhood education*. Mahwah, NJ: Lawrence Erlbaum.

Fuchs, L. S., Compton, D. L., Fuchs, D., Paulsen, K., Bryant, J. D., & Hamlett, C. L. (2005). The prevention, identification, and cognitive determinants of math difficulty. *Journal of Educational Psychology*, *97*, 493–513.

Fuchs, L. S., & Fuchs, D. (2001). Principles for the prevention and intervention of mathematics difficulties. *Learning Disabilities Research and Practice*, *16*, 85–95.

Fuchs, L. S, & Fuchs, D. (2005). Enhancing mathematical problem solving for students with disabilities. *Journal of Special Education*, *39*(1), 45–57.

Fuchs, L. S., Fuchs, D., Hamlet, C. L., Powell, S. R., Capizzi, A. M., & Seethaler, P. M. (2006). The effects of computer-assisted instruction on number combination skill in at-risk first graders. *Journal of Learning Disabilities*, *39*(5), 467–475.

Fuchs, L. S., Fuchs, D., & Hollenbeck, K. N. (2007). Extending responsiveness to intervention to mathematics at first and third grade. *Learning Disabilities Research and Practice*, *22*(1), 13–24.

Fuchs, L. S., Fuchs, D., & Karns, K. (2001). Enhancing kindergarteners' mathematical development: Effects of peer-assisted learning strategies. *The Elementary School Journal*, *101*, 495–511.

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., et al. (2003). Enhancing third-grade students' mathematical problem solving with self-regulated learning strategies. *Journal of Educational Psychology*, *95*, 306–315.

Fuchs, L. S., Fuchs, D., Yazdian, L., & Powell, S. R. (2002). Enhancing first-grade children's mathematical development with peer-assisted learning strategies. *School Psychology Review*, *31*, 569–583.

Geary, D. C. (1990). A componential analysis of an early learning deficit in mathematics. *Journal of Experimental Child Psychology*, *33*, 386–404.

Geary, D. C. (1993). Mathematical disabilities: Cognitive, neuropsychological, and genetic components. *Psychological Bulletin*, *114*, 345–362.

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities*, *37*, 4-15.

Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: A longitudinal study of process and concept deficits in children with learning disability. *Journal of Experimental Child Psychology*, *77*, 236–263.

Gersten, R., & Chard, D. (1999). Number sense: Rethinking arithmetic instruction for students with mathematical disabilities. *Journal of Special Education*, *33*, 18–28.

Gersten, R., Jordan, N. C., & Flojo, J. R. (2005). Early identification and intervention for students with mathematics difficulties. *Journal of Learning Disabilities*, *38*(4), 293–304.

Griffin, S. A., Case, R., & Siegler, R. S. (1994). Rightstart: Providing the central conceptual prerequisites for first formal learning of arithmetic to students at risk for school failure. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 24–49). Cambridge, MA: MIT Press.

Gross-Tsur, V., Manor, O., & Shalev, R. S. (1996). Developmental dyscalculia: Prevalence and demographic features. *Developmental Medicine and Child Neurology*, *38*, 25–33.

Guilford, J. P. (1954). *Psychometric methods* (2nd ed.). New York: McGraw-Hill.

Hanich, L. Jordan, N. C., Kaplan, D., & Dick, J. (2001). Performance across different areas of mathematical cognition in children with learning difficulties. *Journal of Educational Psychology*, *93*(3), 615–626.

Harcourt Assessment. (2003). *Stanford Achievement Test–10th Edition*. San Antonio, TX: Author.

Individuals With Disabilities Education Improvement Act of 2004, 20 U.S.C. § 1400 *et seq*. (2004).

Jordan, N. C., Hanich, L. B., & Kaplan, D. (2003). Arithmetic fact mastery in young children: A longitudinal investigation. *Journal of Experimental Child Psychology*, *85*, 103–119.

Jordan, N. C., Kaplan, D., & Hanich, L. B. (2002). Achievement growth in children with learning difficulties in mathematics: Findings of a two-year longitudinal study. *Journal of Educational Psychology*, *94*, 586–597.

Jordan, N. C., Kaplan, D., Oláh, L. N., & Locuniak, M. N. (2006). Number sense growth in kindergarten: A longitudinal investigation of children at risk for mathematics difficulties. *Child Development*, *77*(1), 153–175.

Kroesbergen, E. H., & Van Luit, J. E. H. (2003). Mathematics interventions for children with special educational needs: A meta-analysis. *Remedial and Special Education*, *24*, 97–115.

Lewis, C., Hitch, G. J., & Walker, P. (1994). The prevalence of specific arithmetic difficulties and specific reading difficulties in 9- to 10-year-old boys and girls. *Journal of Child Psychology and Psychiatry*, *35*, 283–292.

Mercer, C. D., Jordan, L., & Miller, S. P. (1996). Constructivistic math instruction for diverse learners. *Learning Disabilities Research and Practice*, *11*, 147–156.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Ostad, S. (1998). Developmental differences in solving simple arithmetic word problems and simple number-fact problems: A comparison of mathematically disabled children. *Mathematical Cognition*, *4*(1), 1–19.

Parmar, R. S., Cawley, J. F., & Frazita, R. R. (1996). Word problem-solving by students with and without mild disabilities. *Exceptional Children*, *62*(5), 415–429.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. Boston: Houghton Mifflin.

Swanson, H. L. (2001). Reading intervention research outcomes and students with learning disabilities: What are the major instructional ingredients for successful outcomes? *Perspectives*, *27*(2), 18–20.

Swanson, H. L., Hoskyn, M., & Lee, C. (1999). *Interventions for students with learning disabilities: A meta-analysis of treatment outcomes*. New York: Guilford.

Trochim, W. (1984). *Research design for program evaluation: The regression-discontinuity approach*. Beverly Hills, CA: Sage.

Van de Walle, J. A. (2004). *Elementary and middle school mathematics: Teaching developmentally*. Boston: Allyn & Bacon.

Vaughn, S., & Fuchs, L. (2003). Redefining learning disabilities as inadequate response to instruction: The promise and potential problems. *Learning Disabilities Research and Practice*, *18*(3), 137–146.

Vaughn, S., Linan-Thompson, S., & Hickman-Davis, P. (2003). Response to treatment as a means of identifying students with reading/learning disabilities. *Exceptional Children*, *69*, 391–409.

Vaughn, S., Moody, S. W., & Schumm, J. S. (1998). Broken promises: Reading instruction in the resource room. *Exceptional Children*, *64*(2), 211–225.

Woodward, J., & Baxter, J. (1997). The effects of an innovative approach to mathematics on academically low-achieving students in inclusive settings. *Exceptional Children*, *63*, 373–388.

Diane Pedrotty Bryant, PhD, is a professor of special education in the Learning Disabilities/Behavior Disorders Program in the Department of Special Education in the College of Education at the University of Texas (UT) at Austin and a fellow in the Mollie Villeret Davis Professorship in Learning Disabilities. She also serves as a project director for the development of an early mathematics model in the Vaughn Gross Center for Reading and Language Arts at UT. Her major research interests include studying effective practices for early mathematics intervention and reading instruction for students with learning disabilities.

Brian R. Bryant, PhD, lives and works in Austin, Texas. He is a lecturer in the Department of Special Education in the College of

Education at the University of Texas (UT) at Austin. He also serves as the project coordinator for the early mathematics assessment and response-to-intervention model in the Vaughn Gross Center at UT. His research interests include investigating the development and validation of early mathematics measures and interventions and the identification of learning disabilities.

Russell Gersten, PhD, is a director of the Instructional Research Group, a nonprofit educational research institute in Long Beach, California. He is also a professor emeritus in the College of Education at the University of Oregon. His major research interests are the study of the process of effectively translating research into classroom practice, instructional research on English-language learners, reading comprehension, and teaching history to students receiving special education services.

Nancy Scammacca, PhD, is a research associate at the Vaughn Gross Center for Reading and Language Arts at the University of Texas at Austin. Her interests include advanced statistical applications, program evaluation, and meta-analytic research.

Melissa M. Chavez, MEd, is the assistant principal and director of special education at the University of Texas Elementary School in Austin. Her research interests include studying effective interventions for students with learning difficulties.