Commentary on Early Identification and Intervention for Students With Mathematics Difficulties

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J Learn Disabil 2005 38: 340
DOI: 10.1177/00222194050380041001

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Findings from research studies in the United States (Badian, 1983), Norway (Ostad, 1998), Israel (Gross-Tsur, Manor, & Shalev, 1996), and Europe (Kosc, 1974) have shown that 5% to 8% of school-age children exhibit some form of mathematics disabilities (MD) and long-term problems associated with mathematics difficulties (Geary, 2004; Griffin & Case, 1997). With many of these students, reading disabilities (RD) and attention-deficit/hyperactivity disorder (ADHD) have been identified as comorbid disorders (Geary, 2004; Gross-Tsur et al., 1996). For some students, mathematical difficulties or disabilities may be observed as a developmental delay in procedural strategies, whereas other students may demonstrate developmentally different characteristics that remain persistent across the grades (Geary, 1993; Jordan, Hanich, & Kaplan, 2003; Rivera, 1997). Notably, the work of David Geary (1990, 1993), Jordan and Montani (1997), and Jordan et al. (2003) and their colleagues has informed the field's understanding of the nature of MD in young students. Also, whole-class intervention programs such as *Number Worlds* (Griffin, Case, & Siegler, 1994) and *Peer Assisted Learning Strategies* (Fuchs, Fuchs, & Karns, 2001; Fuchs, Fuchs, Yazdian, & Powell, 2002) have offered effective practices for teaching numeracy skills to low-achieving students.

Compared to the knowledge base in early RD, early difficulties in mathematics and the identification of MD in later years have been less researched and understood (Robinson, Menchetti, & Torgesen, 2002). However, an emergent body of empirical research is suggesting possible predictors of MD, and, thus, there is a need to further validate these predictors and to identify effective interventions for young children who are demonstrating MD (Gersten, Jordan, & Flojo, in this issue).

Borrowing from early reading research and the "prevention first" model (Chard et al., in press; Robinson et al., 2002), we can surmise that without early identification and intervention, many students with MD may not develop a level of mathematics proficiency that is sufficient for success on high-stakes assessment administered in the early grades. Thus, it behooves educators to be able to identify at-risk, struggling students who are demonstrating difficulties with mathematics, to provide the necessary instruction that boosts the core curriculum, and to provide more intensive instruction for students who do not respond to typical or core instruction.

Gersten et al. (in this issue) present important findings from the scant body of research on MD concerning early identification and intervention. They have highlighted the research pertaining to three key areas: (a) the nature of mathematics difficulties; (b) number sense, which is referenced across multiple sources (e.g., National Council of Teachers of Mathematics, 2000; National Research Council, 2001) as important for young children's mathematical development; and (c) instructional implications related to preliminary findings about the predictors and measures of mathematical proficiency. Based on this limited but informative research base, Gersten et al. provide their perspectives on the goals of early, intensive intervention, including a focus on increasing fluency with basic arithmetic combinations (cited as a correlate of MD), developing basic number sense principles (e.g., quantity discrimination, counting knowledge), and including other number sense components (e.g., estimation, place value, reasonableness of answer).

This early grades curricular emphasis is supported by the National Council of Teachers of Mathematics (NCTM)'s (2000) *Principles and Standards for School Mathematics*. As noted in the Number and Operation Standard for Grades pre-K–2, "teachers must help students strengthen their sense of number, moving from the initial development of basic counting techniques to more sophisticated understandings. . . . Students should develop efficient and accurate strategies that they understand . . ." (p. 79). The purpose of this commentary is to reflect on the key highlights of Gersten et al.'s article by connecting their information to other relevant sources (e.g., NCTM) and findings related to the nature of MD, early mathematics instruction, and differentiating instruction for struggling students.

Nature of Mathematical Difficulties

Gersten et al. (in this issue) summarize the empirical body of research, which features a series of studies and longitudinal research that have examined the characteristics of young students who exhibit mathematical difficulties in arithmetic combinations, counting strategies, and number sense compared to their typically achieving peers. Findings have shown that students with low mastery of arithmetic combinations showed little progress compared to students who demonstrated mastery of arithmetic combinations over a 2-year period in retrieval of basic combinations in a timed condition. According to Geary (2004), this deficit appears to be persistent and characteristic of a developmental difference suggesting that these children may have some form of memory or cognitive deficit that may lead to the identification of a mathematics learning disability. Thus, "deficits in calculation fluency appear to be a hallmark of mathematics difficulties" (Gersten et al., in this issue, p. 296).

In examining counting strategies (e.g., counting all, counting on, decomposition; Siegler & Shrager, 1984), findings have suggested that children with low levels of number knowledge make significantly more errors using counting strategies than typically performing students or students who had weak arithmetic skills but had benefited from instruction in counting strategies. Notably, students with both mathematics difficulties and reading difficulties (MD + RD) and mathematics difficulties only make more counting errors and use immature counting strategies more often and for a longer duration than their peer group (Jordan et al., 2003; Jordan & Montani, 1997).

Gersten et al. (in this issue) also provide an overview of the findings related to *number sense,* which has been explained as "fluidity and flexibility with numbers, the sense of what numbers mean, and an ability to perform mental mathematics and to look at the world and make comparisons" (Gersten & Chard, 1999, pp. 19–20). The NCTM (2000) described children's number sense 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" (p. 79), and acknowledged "flexibility in thinking about numbers" as a hallmark of number sense. According to Gersten et al.'s overview of number sense research, counting and quantity discrimination are important factors of this construct, whereas Gersten and Chard (1999) discussed discriminating quantity and identifying missing numbers in sequence (i.e., counting) as indicators of number sense. Although number sense may be linked to informal mathematical experiences at home or prior to kindergarten, Gersten et al. identify ways (e.g., counting, simple computation, sense of quantity, use of mental number lines) to develop number sense in kindergarten as a means for helping students to "catch up." For instance, research conducted by Griffin, Case, and Siegler (1994) on developing young children's number sense through the use of a mental number line showed improvement in number knowledge and simple addition and subtraction combinations.

In thinking about the importance of children's understanding of counting as it relates to number sense and to calculation abilities, findings from several studies (e.g., Camos, 2003) have offered information about counting knowledge. Although this information goes beyond Gersten et al.'s article, it may be applicable to researchers who are developing interventions for students who are struggling with early numeracy skills (e.g., quantity discrimination, counting, number identification) that are most predictive of mathematics failure. Several studies have focused on the development of counting skills by describing the specific strategies inherent in the act of counting. For example, Newman, Friedman, and Gockley (1987) found that 6-year-old students used subgroups as a counting strategy. These researchers found that the size of the subgroup (i.e., small numerosity) and the arrangement of the objects (e.g., linear, arrays) within the subgroups influenced how the objects were counted (e.g., by twos, threes). Towse and Hitch (1996) found that decreasing the density of the objects facilitated the ability of 7-year-olds to figure out "already counted" objects from "to be counted" objects, which is an important skill that facilitates arriving at the correct count.

The National Research Council (NRC; 2001), in its *Adding It Up* report, stated that they have drawn from research literature to provide content about the mathematics that children should learn and about how effective mathematics instruction should occur. Regarding counting knowledge, and based on the work of Gelman and Gallistel (1978), the NRC cited the following counting principles as a basis for counting: (a) one-to-one correspondence, (b) stable order (counting words are stated in a consistent order), (c) cardinality (the last counting word indicates the number of objects in a given set), (d) abstraction (any group of objects can be collected to count), and (e) order irrelevance (counting objects in any sequence does not alter the count). Accordingly, the NRC (2001) described the ability to count competently as consisting of "mastery of a symbolic system, facility with a complicated set of procedures that require pointing at objects and designating them with symbols, and understanding that some aspects of counting are merely conventional, while others lie at the heart of its mathematical usefulness" (p. 159).

Counting is indeed a skill that factors into the notion of number sense as measured by the *Number Knowledge Test* and identified by Siegler (1988) as one of three knowledge bases (number–symbol correspondence and order irrelevance are the other two) that must be manipulated in solving arithmetic computations. The NRC (2001) noted that "when children can count consistently to figure out how many objects there are, they are ready to use counting to solve problems" (p. 168). It appears that poor conceptual understanding of counting may contribute to delayed ability in using counting strategies to solve arithmetic combinations and affects the ability to detect and correct counting errors (Geary, 2004). Hence, counting knowledge appears to be an important requisite skill for number sense.

Finally, Gersten et al. (in this issue) acknowledge the need for students to learn the vocabulary of mathematics. Long ago, Wiig and Semel (1984) noted that the vocabulary of mathematics is conceptually difficult—that is, students must understand the meaning of the mathematical vocabulary as well as the meaning of each mathematical symbol (e.g., <, >) because, unlike reading, contextual clues are limited or nonexistent. Prior to entering kindergarten, children are immersed in contextual environments that "teach" informal mathematics. According to Ginsburg (1997), "children encounter quantity in the physical world, counting numbers in the social world, and mathematical ideas in the world of story and literature" (p. 21). The language of this informal mathematics includes terms such as *greater than, less than, one more than, as big as, equal to,* and so forth, and is evident in numerical and quantitative encounters associated with daily living. Although all children seem to learn basic informal mathematics, children living in poverty "perform at a somewhat lower level on certain mathematical tasks than do their more affluent peers" (Ginsburg, 1997, p. 22). Thus, group differences in informal mathematics learning, including vocabulary development, are noted in informal mathematics instruction and certainly influence the formal mathematics instruction beginning in kindergarten. For example, in a recent focus group with kindergarten teachers where the topics included mathematics instruction and low-achieving students, teachers described difficulties that their struggling students demonstrated with the vocabulary of mathematics, number, and quantity (Bryant, Bryant, Kethley, Kim, & Pool, 2004).

From an instruction standpoint, we know that good vocabulary teaching involves identifying the concepts that are most critical for students to learn to understand mathematics instruction. Teachers need to help students link the meanings of new words to prior knowledge and provide multiple opportunities to engage students in meaningful ways that require applications of the new vocabulary across situations. For instance, when preparing a lesson, teachers can identify important vocabulary that might be difficult for students to learn implicitly. For instance, the terms *greater than* and *less than* are typical vocabulary meanings for early mathematics instruction. Students must understand the notion of quantity and number as they relate to these concepts. The new vocabulary can be taught explicitly and reinforced throughout the lesson. Teachers can use the new vocabulary across contexts, such as during science or reading instruction, and informally during the school day. Bryant, Goodwin, Bryant, and Higgins (2003) found that depending on the desired depth of word knowledge, instruction that actively engages students with graphic depictions (e.g., semantic maps) and that is paired with explicit instruction seems most helpful in teaching vocabulary. Moreover, vocabulary instruction on a small number of words at any given time seems most beneficial when students work in small groups or in pairs on vocabulary activities.

Early Mathematics Instruction

Gersten et al.'s article (in this issue) provides direction for researchers interested in validating the effectiveness of interventions for students who are identified as exhibiting MD. Drawing from the highlighted findings, it seems logical to consider fluency with arithmetic combinations, counting strategies, and number sense as areas to focus intervention efforts taking into consideration the varying deficits associated with mathematical difficulties (e.g., MD + RD versus MD only).

Gersten et al. (in this issue) discuss instructional implications of focusing on fluency of basic arithmetic combinations and number sense, recommending the use of explicit instruction to teach mature counting strategies to promote retrieval (i.e., automaticity) of arithmetic combinations (Robinson et al., 2002). For example, learning about and applying the principles of decomposition and commutativity conceivably can contribute to the efficient and effective use of counting strategies and reduce the incidence of counting errors (Geary, 2003). In fact, the NRC (2001) suggested that a combination of explicit instruction with open-ended problem solving and teacher-facilitated instruction should be implemented as part of the NCTM's reform-based mathematics instruction. Thus, an instructional emphasis on explicit instruction does not need to be mutually exclusive of the reform-based standards instruction (i.e., teacher facilitated, inquiry based) that is pervasive in many of today's classrooms. For example, take the task of having kindergarten students use concrete materials, such as cubes, to show different ways of representing "10." In thinking about the requisite abilities associated with this task, students need to be able to count to 10, to use one-to-one correspondence to count the cubes, to discriminate between "already counted" and "to be counted" in each display of 10, and to show different patterns or subgroups of 10. Some students may require brief, explicit instruction in a small group on some of these requisite abilities to participate more successfully with understanding in the class lesson. This explicit instruction can be provided in a variety of ways. For instance, before the lesson, while other students are busily engaged in group or independent work, the teacher can work with those students who require explicit instruction on the requisite skills necessary for the upcoming lesson. During the lesson, explicit instruction can be conducted while other groups of students work to generate solutions to the problem. Instruction should be delivered with good pacing and monitoring, so that time is used efficiently and student learning is assessed.

Since the first publication of its standards in 1989, the NCTM has advocated changes in mathematics curriculum, instruction, assessment, and teacher preparation programs. At the heart of the reform movement has been a shift from predominantly skills-based instruction to an inquiry-based approach that encompasses active student learning rooted in problem-solving situations facilitated by teacher guidance and questioning (Rivera, 1997). "Knowing" mathematics and constructing mathematical knowledge is viewed as an ongoing, social activity within a dynamic classroom culture, and the teacher's role is to facilitate students' inquiry work (Cobb, Yackel, & Wood, 1992). However, findings from naturalistic research in reform-based mathematics classrooms suggest a need for mediated instruction for older students with MD to engage them actively in the learning process (Woodward, 2004). Moreover, preliminary findings examining the degree to which effective instructional features are present in kindergarten, first-, and second-grade mathematics textbooks show limited use of those features that are important for teaching struggling students (Bryant, Bryant, Kethley, Kim, Pool, et al., 2004). It is critical to link Gersten et al. (in this issue) instructional implications (e.g., providing explicit instruction on specific skills and procedures) to today's reform-based mathematics instruction by identifying frameworks or models for differentiating instruction for struggling students.

Differentiating Instruction for Struggling Students

Fuchs and Fuchs (2001) identified a framework for the prevention and intervention of mathematics difficulties that consists of three levels of prevention and intervention, including primary, secondary, and tertiary. Fuchs and Fuchs characterized primary prevention as one of focusing on universal design; that is, instruction that benefits *all* students, including those with learning problems. Secondary prevention centers on adaptations that are feasible to implement, nondisruptive to the targeted child, and nonintrusive for the rest of the class. Finally, Fuchs and Fuchs discussed tertiary prevention as intensive and individualized, involving special resources and often delivered by the special education teacher.

Vaughn (2002) described the conceptualization of prevention and intervention through a "response to intervention" tiered model for struggling readers in the early grades. The 3-tier reading model provides a framework for a data-driven delivery of differentiated instruction for all students, including struggling readers. Briefly, Tier 1 consists of evidence-based core instruction for all students, whereas Tier 2 includes supplemental instruction and ongoing progress monitoring for identified struggling students. Tier 3 is reserved for those students who do not benefit from Tier 1 and 2 instruction, thus requiring additional intensive reading intervention, which may be delivered by the special education teacher.

As noted by Gersten et al. (in this issue), there is a need for differentiation of mathematics instruction beginning in kindergarten (Case et al., 1992). According to Van Luit (2000), mathematical interventions may vary not only by child but also by the tasks within topics that may necessitate instructional adaptations. Thus, core (Tier 1) mathematics instruction, which centers on reform-based standards, may indeed need instructional boosts or adaptations for those students initially identified as struggling with mathematics skills that are most predictive of mathematics failure.

Bryant and Bryant (1998) proposed an adaptations framework as a means for identifying appropriate adaptations for students with disabilities. Initially linked with identifying assistive technology adaptations, the conceptualization of the adaptations framework was expanded to identifying appropriate reading adaptations (i.e., differentiating instruction) for elementary (VGCRLA, 2001) and secondary (VGCRLA, 2002) struggling readers. More recently, the adaptations framework is being implemented in early mathematics instruction with struggling students. Simply put, the adaptations framework involves identifying the setting tasks (e.g., adding simple combinations) and the related requisite abilities (e.g., counting knowledge, counting strategies, order irrelevance); the student characteristics, both strengths and weaknesses associated with the task's requisite abilities; and possible instructional adaptations that can be used to help the student learn the instructional objective. As part of the adaptations framework, instructional adaptations can be made in one or more of the following areas: delivery of instruction (e.g., grouping formats, additional explicit instruction), instructional content (e.g., more instruction on requisite skills), instructional activities (e.g., differentiated activities), and instructional materials (e.g., number lines, manipulatives). Evaluation of student learning (i.e., progress monitoring) is the final component of the adaptations framework.

Examples of instructional adaptations for core instruction (Tier 1) might include practices that have been identified in a synthesis of empirical research on effective interventions for low-achieving students (Baker et al., 2002) and in research-based principles associated with primary (Tier 1) preventative instruction (Fuchs & Fuchs, 2001). Research-based interventions for low-performing students that can be used to adapt instruction for struggling students include peer-assisted tutors (Baker et al., 2002; Fuchs et al., 2001; Fuchs et al., 2002), explicit instruction in teaching procedural and conceptual strategies (e.g., calculation principles, commutativity; Baker et al., 2002; Gersten et al., in this issue), verbalizations of cognitive strategies (Fuchs & Fuchs, 2001), and physical and visual representations of number concepts (Fuchs et al., 2001; Gersten et al., in this issue).

Based on our preliminary findings of current mathematics textbooks (Bryant, Bryant, Kethley, Kim, Pool, et al., 2004), these interventions, in our view, are adaptations of current practice and conceivably can be implemented in small, homogeneous, teacher-directed groups to support core (Tier 1) instruction. The challenge is to learn more about how these instructional adaptations can be implemented by general education teachers, who may not be prepared to provide differentiated, adapted instruction or who do not view adaptations as particularly feasible within the typical mathematics instructional period.

Gersten et al.'s (in this issue) intervention recommendations for students with MD hold promise for adapting core (Tier 1) instruction. What is less clear is a description of what Tier 2 instruction should look like. We can draw ideas from Gersten et al. that the Tier 2 focus may be on more intensive, supplemental intervention in building fluency in arithmetic combinations through "shortcuts" that tap calculation principles. Intensive, supplemental instruction in the requisite skills for number sense (e.g., counting knowledge) may also constitute part of the Tier 2 package. At this time, the role of other number sense skills (e.g., estimation) and foundational vocabulary understanding remains unclear.

Conclusions

Gersten et al. (in this issue) provide an excellent summary of the highlights of key findings in the area of mathematical difficulties, number sense, and instruction. The purpose of this commentary was to reflect on these findings and to expand the findings to other related sources, studies, and practices. The findings presented in the Gersten et al. article provide a sense of optimism that the area of early mathematics and struggling students is gaining national attention as an area in need of research. Special series such as this one, conference sessions, research studies, and symposia can further the badly needed discussion in the identification of mathematics difficulties and early intervention.

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