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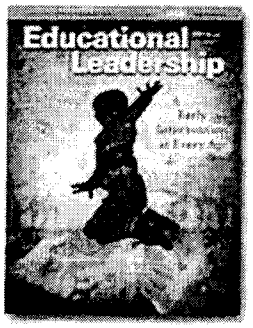
The Need for Number Sense



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The roots of many students' math difficulties are evident as early as kindergarten.

In 1st grade, Kendra was a confident student. She had acquired reading skills easily in kindergarten. Although Kendra was able to keep up with the primary school math curriculum, she had trouble counting and learning addition and subtraction combinations, and she relied on her fingers for computation.

By 4th grade, Kendra became frustrated in math. She couldn't pass the "two-minute" facts tests in addition, subtraction, multiplication, and division. Her ability to solve written calculations was not fluent, and she got mixed up on problems that required several steps. Although her strong language skills helped her talk her way through many problems, she spent so much time computing that she sometimes forgot the goal of the problem.

In middle school, Kendra experienced difficulties factoring, computing with rational numbers, and solving algebraic equations, all skills that depend on fluency with basic calculation. Because math was so difficult for Kendra, she gradually lost enthusiasm for the subject.

Barriers to Mastering Math

Although mathematical difficulties and disabilities come in different forms, Kendra's situation highlights key issues for understanding students who struggle in math. Students with *math disabilities*, or *dyscalculia*, usually fall at or below the 15th percentile on standardized math tests, despite having average or above average intelligence (Jordan, 2007). Math disabilities are estimated to appear in 6 to 10 percent of the population (Barberisi, Katusic, Colligan, Weaver, & Jacobsen, 2005). Dyscalculia is more common in boys (about 2 boys to every girl) and occurs with dyslexia about 60 percent of the time.

Students with *math difficulties* appear less impaired than those with math disabilities. For example, they perform better on standardized math tests—usually at or below average. Math difficulties, if not addressed, usually persist across grade levels (Geary, 1994).

Learners with math disabilities and math difficulties perform math in much the same way. A signature characteristic of students in both groups is weak computational fluency, or difficulty quickly solving combinations, such as 9 + 7 or 16 - 9 (Gersten, Jordan, & Flojo, 2005). Most students initially solve these problems in a variety of ways (Siegler & Jenkins, 1989). For example, they may quickly count up or down or relate a subtraction combination to a known addition combination. Kindergartners who use their fingers on simple number combinations often stop using them in 1st grade and develop fluency by 2nd grade. By 3rd grade, most students can add and subtract combinations without external supports.

Students with math difficulties, however, start using their fingers later (in 1st grade) and depend on them for longer periods of time. Their fingers are less reliable with larger combinations, and such students often fail to develop the calculation fluency necessary for higher-level math classes.

The Base of the Problem

Many educators assume that learners with math difficulties and disabilities have trouble memorizing facts. As a result, special instruction often focuses on drill. Recent research, however, suggests that deficient *number sense* underlies many math difficulties (Landerl, Bevan, & Butterworth, 2004). Number sense refers to intuitive knowledge of numbers—such as the ability to grasp and compare quantities (6 versus 8); internalize counting principles (the final number in a count indicates the quantity of a set, numbers are always counted in the same order); and estimate quantities on a number line (Berch, 2005).

Mastery of number combinations is tied to knowledge of fundamental number concepts (Baroody & Rosu, 2006). Imagine how hard it would be to memorize arithmetic combinations without understanding how numbers relate to one another. It is easier for students to remember the correct answer of a combination, such as 3 + 2, when they understand its relationship to such combinations as 2 + 3 and 5 - 3.

Early Identification

In today's schools, many math difficulties are not identified until 4th grade or beyond. Math interventions are much less common for young learners than are reading interventions (Jordan, Kaplan, & Hanich, 2002). Schools should routinely screen students for number-sense difficulties in kindergarten, just as most screen students early for literacy problems. Screening for number sense several times during the year can help teachers identify students with actual difficulties and reduce false positives.

The research team that I lead has developed a number-sense screening test for young students (Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan, Kaplan, Olah, & Locuniak, 2006). The core battery covers the following:

- Counting skills and principles.
- Number knowledge (such as recognizing which number is larger or smaller).
- Nonverbal calculation. (The student is shown two chips, which are then hidden. Then three more chips are hidden, and the student indicates how many are now hidden.)
- Story problems with object references. (Jack has 2 pennies. Sue gives him 3 more pennies. How many pennies does Jack have now?)
- Number combinations with no object references. (How much is 2 plus 3?)

We used this screening test to assess about 400 students four times in kindergarten, and we followed more than 300 of these students through 1st grade. We found three distinct number-sense growth trajectories in kindergarten and 1st grade: (1) students who start kindergarten with low number sense and experience little growth, (2) students who start kindergarten with low to moderate number sense but start showing steep growth in the middle of kindergarten, and (3) students who start kindergarten at a high level and remain there. Low-income students are four times more likely to fall in the low-performing, flat-growth group than are middle-income learners.

We also found that number sense at the beginning of kindergarten is highly correlated with math achievement at the end of 1st grade. For the 300 students we followed, number-sense performance during the kindergarten year, along with number-sense growth between kindergarten and 1st grade, accounted for 66 percent of the variance in 1st grade math

achievement. Background characteristics of the students did not explain differences in their achievement levels, over and above number sense.

Our findings, in addition to other evidence (Gersten et al., 2005), indicate that number-sense screening in kindergarten and early 1st grade helps identify students at risk for learning difficulties and disabilities in math. We have also found that the strong predictive value of kindergarten number sense holds into 2nd grade on a calculation fluency measure.

Providing Help

Research offers some important insights for helping learners who struggle or who may be at risk for struggling in math. In kindergarten, these students should receive explicit help representing, comparing, and ordering numbers and joining and separating sets, particularly with totals of 5 or less (Fuson, 1992; National Council of Teachers of Mathematics, 2006). Learners should first manipulate quantities with their fingers or using sets of concrete objects. They should be encouraged to imagine set transformations in their heads without physical representations. For example, the teacher can ask a student, "Imagine 4 pennies. Now take away 1 penny. How many pennies are left?"

Number lists and board games that use number lists, such as Chutes and Ladders, can also help young students develop meaningful knowledge of quantities and number magnitudes (Ramani & Siegler, 2007). Conventional number lines, on the other hand, may confuse young learners because they start with zero (Fuson, 1992).

Laying the Foundation

Although calculation fluency is not sufficient for succeeding in advanced math, such as algebra, it is a necessary foundation. Weak computational fluency, a distinguishing feature of math difficulties, reflects basic deficiencies in number sense. Helping students build number sense right from the start gives them the background they need to achieve in later years.

If Kendra had developed the number sense she needed in 1st grade, she would have been better prepared to complete the more complex problems that frustrated her in 4th grade. With that success under her belt, she might have continued on to master factoring and equations and maintained an interest in math that could carry her to calculus and beyond. Identifying students like Kendra and intervening early is one key to keeping students on track for math success.

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