Understanding of the equal sign in Grade 2 predicts later algebra skills

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All over the world, young people seem to struggle with algebra. Each year in the US alone, an estimated six million high school students and two million college freshmen encounter difficulties learning this subject. This is an important issue, since algebraic competence is a major determinant of college access and career prospects.

Simply put, “algebra” is the study (and the application) of mathematical symbols, where letters represent numbers, which in turn represent quantities. Algebra is “equation solving” because it puts numbers or quantities into relations.

To understand algebra, it is essential to grasp the concept of the equal sign. Superficially, the equal sign is simply a symbol that occurs between a mathematical problem and its solution. Yet its meaning extends further – indeed, the equal sign signals certain relations. However, school curricula rarely specify that children need to learn that the equal sign reflects a concept that helps us evaluate and model the world.

“Without a sense for relational understanding, the algebraic principle of maintaining equality is nonsensical,” says cognitive psychologist Caroline Byrd Hornburg, “and children are left struggling to memorize countless, seemingly arbitrary rules when solving equations.” To date, only a few studies have examined the causal effects of early understanding of the equal sign on later algebra performance.

Recent research by Percival G. Matthews and Lynn S. Fuchs has shown that understanding of the equal sign in Grade 2 predicts children’s algebra knowledge in Grade 4, after accounting for demographic factors (age at testing, ethnicity, gender), as well as individual differences (IQ, eligibility for tutoring and/or subsidized lunches, maladaptive behavior such as inattentiveness or hyperactivity).

Matthews and Fuchs tested 191 second graders to assess their basic arithmetic (i.e., addition and subtraction) and number-line estimation skills; in the latter case, they were asked to locate a given number on a number line from 0 to 100). To evaluate their understanding of the equal sign, the researchers asked the children to solve open equations, or math equivalence problems.

A few examples:

8 + 4 = _

_ = 3 +4

5 + 2 = 7; true or false?
Two years later, when the children were in Grade 4, the researchers tested their algebraic reasoning. To that end, the children were asked to solve such problems as “If $3 + 4 = X + 5; X = _$” or were presented with function tables and asked to identify the relationships between numbers and letters. For example, “If $Y = 7$ and $3Y = 21$, then if $Y = 5, 3Y = _$.”

The researchers found that understanding of the equal sign in Grade 2 was the best predictor of performance on algebraic tasks in Grade 4. Indeed, it was a more powerful predictor than IQ and attentive behavior in Grade 2 combined, and it was also more powerful than any of the other Grade 2 math skills (i.e., arithmetic and number lines).

Interestingly, the researchers also found that second graders generally had more difficulty solving math problems expressed in a non-standard way, such as “$_ = 6 + 5$,” rather than in a more familiar way, such as “$6 + 5 = _$.” In the first case, the average child solved only 43 percent of these items correctly, versus 76 percent in the latter case. It is likely that some of the children in the study had not yet fully grasped the meaning of the equation sign – beyond the fact that it separates a mathematical problem and its solution.

“The equal sign reflects a concept that helps us evaluate and model the world.”

As Matthews and Fuchs conclude, “If algebra serves as a gatekeeper for students’ future academic and economic success, then it appears that knowledge of the equal sign serves as a key to the gate.”

If children and youth are to gain a better understanding of the fundamental principles of algebra, it would be wise to focus more attention on helping students in the early grades to truly understand the significance of the equal sign. Educators and parents, as well as education policymakers, should also be made aware of the importance of this concept.

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