How do Balance Scales Shape K–2 Students' Understandings of Equations?

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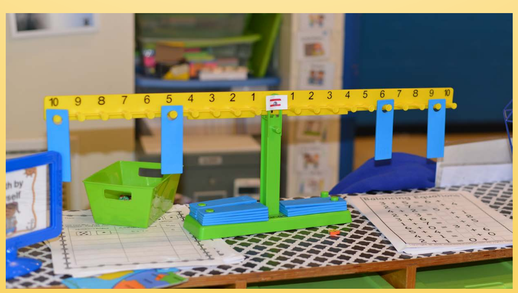
Background

Project LEAP (*Learning through an Early Algebra Progressio*n) is a decade-long series of projects that has involved developing and testing a model of early algebra instruction framed by core algebraic ideas and thinking practices. In a series of projects aimed at testing the effectiveness of our Grades 3–5 early algebra intervention and documenting progressions in students' algebraic thinking, we found that students who experienced the intervention outperformed their control counterparts on measures of algebra understanding and used more algebraic strategies in problem solving (Blanton et al., 2015; Blanton, Isler-Baykal et al. 2019; Blanton, Stroud et al., 2019).
In our current work, we are extending our Grades 3–5 program of research to develop and test a Grades K–2 intervention with the goal of establishing a research-vetted Grades K–5 program of early algebra education.

In the work described here, we focus on the core concept of **mathematical equivalence** and explore Grades K–2 students' shifts in thinking as they engaged in tasks designed to help them explore this concept and develop a relational view of the equal sign (i.e., a view that the equal sign indicates an equivalence relationship between quantities or expressions).

Our study was framed around the idea that **mathematical tools** can shape students' thinking (Vygotsky, 1978). We focused on the use of balance scales and explored the ways in which these tools shaped students' thoughts about the meaning of the equal sign and equations.

Research question
How does students' use of balance scales mediate their relational understanding of the equal sign?



Number balance representing the equation 10 + 5 = 6 + 9.

Method

Participants
Twenty-one students across Grades K–2 from two schools who were participating in a larger study involving the design of an early algebra intervention. One school was selected due to its diversity in terms of race and SES and the other because it serves a high percentage of students with learning difficulties.

Data collection
Pre/mid/post teaching experiment interviews engaged students in solving true-false (e.g., 5 = 5, 5 = 1 + 4, 4 + 5 = 9 + 3) and open number equations (e.g., 4 = 3 + ___, 4 + ___ = 8 + 4) with the use of pan balances and number balances.

Data analysis
Analysis of the videotaped interviews started with a grounded approach in which coders freely noted what they noticed in students' responses about mathematical equivalence and the instructional prompts, discussion, and tools that may have contributed. It subsequently narrowed to a focus on the affordances of the balance scales for mediating students' relational understandings of the equal sign. We focus here not on change in students' understanding over the course of the school year but on the ways in which the use of tools shaped students' thinking about the equal sign across all interviews.

References

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Results

The balance scales…

helped students refine initial interpretations
e.g., A kindergartener initially thought 5 = 1 + 4 was false, then found otherwise using a pan balance and reflected on why: "It's right, cause, look, 1 [holding up one finger on left hand] and 2, 3, 4, 5 [holding up four fingers on right hand]!"

encouraged trial-and-error equation solving
e.g., Given 4 + 2 = ___ + 4, a second grader initially wrote "6" in the blank (a common "operational" response). Seeing the scale did not balance, he moved the weight around to find correct solution. Upon reflection, he felt still conflicted by the result.

encouraged productive "tinkering" and play
e.g., Two first graders used the number balance to figure out how to change 3 + 5 = 7 to make it true (3 + 4 = 7 or 3 + 5 = 8).

helped students notice equation structure
e.g., After solving 4 + 2 = ___ + 4 with trial and error, a first grader said, "Oh! Because it's the same. Because this is two and this is four [pointing to weights on left side of scale] and this is two and this is four [pointing to weights on right side of scale]."

helped reveal students' difficulties
Many students revealed a lack of attention to the equal sign and its role in an equation, e.g., a kindergartener placed 2 and 3 cubes on same side of a pan balance given 4 + 2 = 3.

Many students neglected parts of equations in their representations, e.g., a second grader placed two weights on the left 4 and one weight on the right 8 given 4 + ___ = 8 + 4. This is indicative of an operational rather than relational view of the equal sign.

Next steps

This exploratory study sets the stage for a larger study to test the effectiveness of the Grades K–2 early algebra intervention that includes the use of balance scales to help students develop relational conceptions of the equal sign.