SMU | Annette Caldwell Simmons School of Education & Human Development

Research in Mathematics Education

Measuring Early Mathematical Reasoning Skills: Developing Tests of Numerical Relational and Spatial Reasoning (#1721100)

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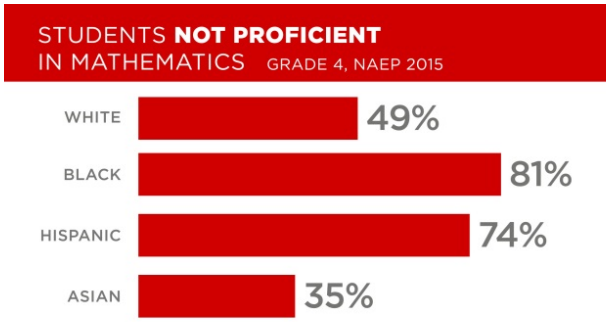
Funder: National Science Foundation's Discovery Research Pre-K-12 Program

Early Mathematics is Critical

The global economy is attuned to a STEM-ready workforce, yet the U.S. continues to struggle to remain at even the median for mathematics achievement for developed and developing countries (and behind *many* industrialized nations), according to the Pew Research Center. And the gaps across race and ethnicity continue to widen. While these standardized global and national report cards collect data largely from high school and middle school students, a growing body of evidence indicates that early mathematics is a key indicator of later achievement. In fact, an examination of the item



$$3 + 8 = \_\_\_ + 6$$

on the 2011 fourth-grade Trends in International Mathematics and Science Study (TIMSS) suggests that students in the United States struggle with numeric relational reasoning concepts, compared to higher-performing countries. **Only 47% of fourth grade students in the U.S. answered this question correctly, compared to 88%, 85%, and 80% correct for Hong Kong, Singapore, and the Russian Federation, respectively.**

Why is Early Mathematics Important?

- Research indicates that early mathematics is the ***strongest predictor of future achievement***, including reading and mathematics achievement (Duncan et al., 2007).
- Students' early mathematics knowledge is a more powerful **predictor of their *future socioeconomic status* (SES)** at age 42 than their family's SES as children (Ritchie & Bates, 2013).
- **Numeric relational reasoning** and **spatial reasoning** are two early mathematics skills particularly predictive of algebraic reasoning, leading to Algebra I, which is a gatekeeper to success in post-secondary efforts in STEM domains, including chemistry, geology, biology and engineering.

The STEM Pipeline Starts in the Earliest Grades

Numeric relational reasoning is closely related to number sense, and is recognized as the ability to mentally solve mathematics equations by examining the relationships between numbers and expressions, which lays the groundwork for understanding in algebra. Similarly, **spatial reasoning**, or spatial sense is also a foundational topic for early childhood mathematics, and moves beyond geometric concepts such as shape identification to focus on understanding, visualizing, and interacting in one's environment.

Research from the last ten years shows that students with strong spatial reasoning abilities are more likely to pursue STEM careers and college degrees that those with weaker spatial abilities (Wai, Lubinski, & Benbow, 2009). And, ***spatial reasoning skills are predictive of STEM career choices***, with many disciplines depending on spatial reasoning abilities including engineering, chemistry, medicine, biology and geology.

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What is MMaRS?

The **Measuring Early Mathematical Reasoning Skills (MMaRS): Developing Tests of Numerical Relational and Spatial Reasoning** project is a $2.5 million research grant from the National Science Foundation's Discovery Research Pre-K-12 Program. The project will develop and evaluate mechanisms for collecting data to understand what students in Grades K-2 are struggling with, particularly focused on these two foundational and predictive early mathematics constructs, **numeric relational reasoning and spatial reasoning**.

Why Do We Need It?

- When teachers have the data to understand what their students are struggling with, they have the tools to intervene, and provide the support for **ALL students** to be successful now, setting a foundation for achievement in short and long-term STEM outcomes.
- 60 percent of Grade 4 students are **not proficient** in mathematics (NAEP, 2015), and by Grade 8, that number jumps to **66 percent**. Numeric relational reasoning and spatial reasoning are concepts critical to success in future mathematics coursework.
- Despite the known importance of these concepts, ***we do not have the mechanisms*** for teachers to understand where students are in their comprehension and utilization of numeric relational and spatial reasoning in Grades K-2.

Where Are We Going?

The MMaRS system is first and foremost, intended to support teachers with the data to intervene early and provide the extra support to students who need it. The MMaRS system has the potential to improve mathematics achievement in the short- and long-term and STEM outcomes, such as STEM degree attainment and career choice. Improving students' numeric relational reasoning and spatial reasoning abilities in Grades K-2 has the potential to positively affect students' overall performance in early mathematics.

Who We Are

Dr. Ketterlin-Geller is a professor, Texas Instruments Endowed Chair, and director of the Research in Mathematics Education Unit at SMU. She has served as principal investigator for numerous funded projects to design formative and summative assessment systems in mathematics, as well as instructional interventions to support students who are struggling. She is the lead developer for a system of algebra-readiness universal screeners and diagnostic assessments for all Texas public school children in grades 2-8. She has published articles and book chapters, and has presented original research findings at local, national, and international conferences. She can be reached by email at lkgeller@smu.edu.

Dr. Perry is a former elementary and middle-school mathematics teacher and also worked at the Texas Education Agency (TEA) as a mathematics assessment specialist and as Assistant Director of Mathematics. She began collaborating with Dr. Ketterlin Geller on statewide assessment initiatives while at TEA and joined the doctoral program at the Simmons School in 2011. Dr. Perry assisted in the development of the Early Grade Mathematics Assessment (EGMA) Relational Reasoning and Spatial Reasoning measures, an international assessment, examining the validity of the interpretations for her dissertation research. She is currently a Research Assistant Professor at the Research in Mathematics Education unit, and can be reached by email at leperry@smu.edu.