Pattern knowledge, but not shape knowledge, predicts fifth-grade math outcomes

Emily R. Fyfe, Bethany Rittle-Johnson, Kerry Hofer, & Dale C. Farran, Vanderbilt University

Fyfe is now at the University of Wisconsin-Madison and Hofer is now at Abt Associates Inc.

Abstract

The contributions of early pattern and shape knowledge to later math achievement remain unknown – largely because the majority of research on early math focuses exclusively on numeracy. Here, 517 children completed a variety of measures at ages 5, 6, 7, and 11, spanning pre-k to fifth grade. Pattern knowledge, but *not* shape knowledge, predicted math achievement in fifth grade, over and above general math and language skills. This was also true for geometry knowledge, indicating that shape knowledge was not uniquely predictive of the most direct outcome.

Background

Patterns are predictable sequences and often considered central to math (Charles, 2005). Pattern interventions have been shown to improve math knowledge relative to controls (Kidd et al., 2014), but recent standards do not include patterning (CCSS, 2010).

Shape knowledge is included in early math standards (CCSS, 2010), and considered critical for later geometric thinking (NRC, 2009). But, there is no evidence linking early shape knowledge to later mathematics outcomes.

Goal

Examine whether pattern and shape knowledge in pre-k, kindergarten, and first grade predict math outcomes in fifth grade within a longitudinal study of over 500 low-income children.

Method: Longitudinal design from pre-k to fifth grade

PARTICIPANTS

517 students from low-income homes, originally recruited from pre-k classrooms and participating in the Peabody Research Institute Middle School Follow Up Project (56% female; 79% Black; M age = 11.0, SD = 0.32; 86% in 5th grade, 14% retained in 4th grade)

EARLY PREDICTORS (pre-K, K, 1st grade)

Two math subscales (pattern and shape) created using items from the Research-based Early Math Assessment (REMA; Clements, Sarama, & Liu, 2008).

Four subtests from the Woodcock Johnson III Tests of Achievement: Quantitative Concepts (math), Applied Problems (math), Letter-Word Identification (reading) and Story Recall (^oral language). (Used W-scores.)

Teacher ratings of work-related skills (Cooper-Farran) and self-regulation (Instrumental Competence Scale).

MATH OUTCOMES (5th grade)

Three subtests from the KeyMath 3 Diagnostic Assessment: Numeration, Algebra, and Geometry (used raw scores). Quantitative Concepts from the Woodcock Johnson (used standard scores).

Created composite "math achievement" measure by summing z-scores across KeyMath and Woodcock Johnson subtests. Also examined Geometry separately.
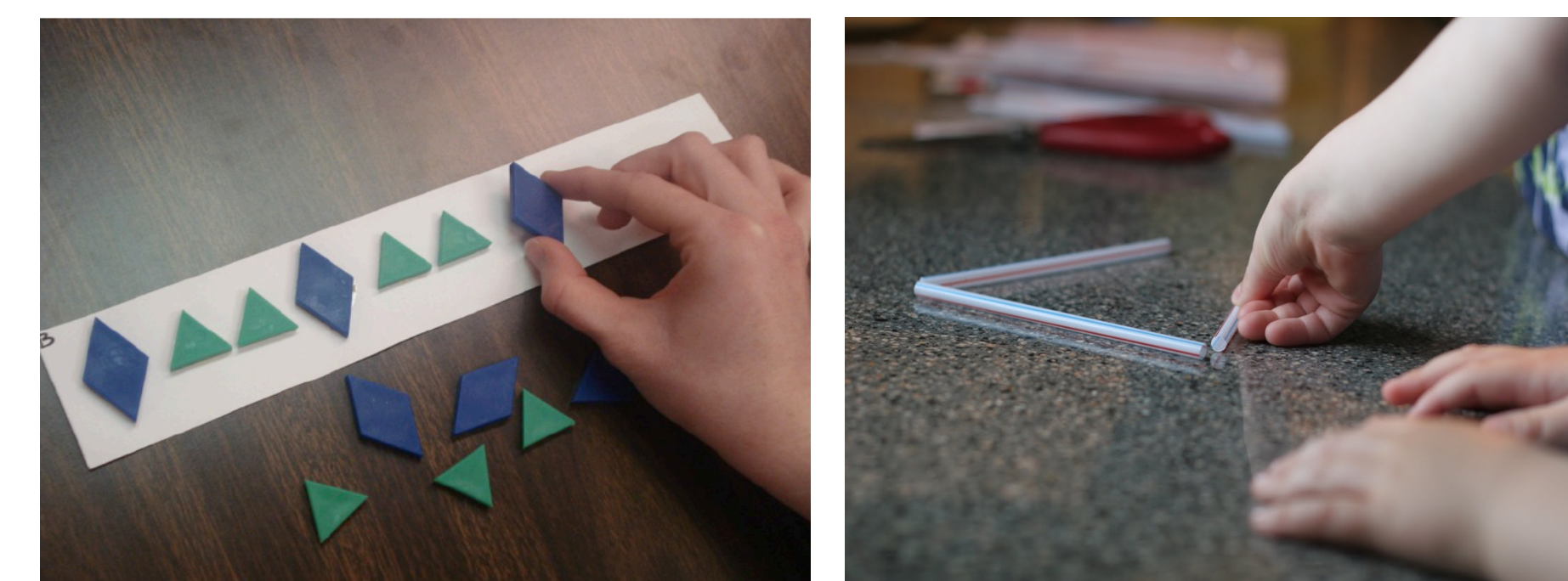
Sample pattern and shape items from Clements, Sarama, & Liu (2008). Extend ABB pattern on the left. Make triangle out of straws on the right.

Results: Predicting fifth-grade math outcomes

DATA ANALYSIS

Imputed missing values via multiple imputation in SPSS. Ran multi-level regression models with student level and school level for each outcome at each time point. All continuous variables were standardized so parameter estimates represent standardized regression coefficients.

RESULTS

Pattern knowledge was a consistent predictor of fifth-grade math achievement and geometry knowledge (βs from .09 to .18). Shape knowledge was not predictive of fifth-grade math achievement, nor was it predictive of geometry knowledge (βs from -.01 to .04).

Regression estimates predicting fifth-grade math from early shape and pattern skills.

	FIFTH-GRADE MATH ACHIEVEMENT			FIFTH-GRADE GEOMETRY		
	Pre-K	*Kindergarten*	*First Grade*	*Pre-K*	*Kindergarten*	*First Grade*
MATH SKILLS						
Shape knowledge	.01 (.04)	.00 (.04)	-.01 (.04)	.02 (.05)	-.01 (.05)	.04 (.05)
Pattern knowledge	.17 (.04)***	.09 (.04)*	.09 (.04)*	.18 (.05)**	.13 (.05)**	.13 (.05)**
Quantitative concepts	.29 (.05)***	.19 (.04)***	.16 (.04)***	.23 (.06)***	.13 (.06)*	.04 (.05)
Applied problems	.16 (.05)**	.27 (.04)***	.31 (.04)***	.10 (.05)	.21 (.05)***	.31 (.05)***
NON-MATH SKILLS						
Reading	.02 (.04)	.06 (.04)	.10 (.04)*	-.07 (.05)	.01 (.05)	.08 (.05)
Oral language	.13 (.04)***	.12 (.03)***	.10 (.03)**	.20 (.04)***	.14 (.04)***	.11 (.04)**
Work-related skills	.06 (.06)	.03 (.06)	.20 (.05)***	.08 (.07)	.00 (.08)	.19 (.07)**
Self-regulation	-.02 (.06)	.17 (.06)*	.04 (.05)	-.04 (.07)	.12 (.08)	-.07 (.07)
CONTROL VARIABLES	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.

Note. Standard errors in parentheses. All variables were standardized and standardized regression coefficients are reported. Control variables include gender, ethnicity, SES composite with material education and level of income, ELL status, pre-k school type, age in fifth-grade, and grade level (fourth or fifth). *p < .05, **p < .01, ***p < .001.

^Oral language was measured using the Renfrew Bus Story in Pre-K and using the WJ-III Story Recall in Kindergarten and First Grade.

Conclusions

Early pattern knowledge uniquely predicted middle-school math achievement and geometry knowledge.

This was true in pre-k, where patterning receives attention (Rittle-Johnson et al., 2015), but also in kindergarten and first grade. Pattern skills mattered over and above general math knowledge.

Early shape knowledge did not predict middle-school math achievement or geometry knowledge after controlling for other math and non-math skills.

Implications

Theories of math development should go beyond numeracy and consider the roles of pattern and shape knowledge.

Early math standards should include pattern knowledge in kindergarten and first grade.

More research is needed on the importance of shape knowledge.

References

- Charles, R. (2005). Big ideas and understandings as the foundation for elementary and middle school mathematics. *Journal of Mathematics Educational Leadership, 73*, 9-24.
- Clements, D. H., Sarama, J. H., & Liu, X. H. (2008). Development of a measure of early mathematics achievement using the Rasch model: The research-based early math assessment. *Educational Psych, 28*, 457-482.
- Common Core State Standards (CCSS). (2010). Retrieved from http://www.corestandards.org/Math/Content/K/G/.
- Kidd, J. K., Pasnak, R., Gadzichowski, K., Gallington, D. A., McKnight, P., Boyer, C. E., & Carlson, A. (2014). Instructing first-grade children on patterning improves reading and math. *Early Education & Development, 25*, 134-151.
- National Research Council. (2009). *Mathematics Learning in Early Childhood: Paths Toward Excellence and Equity.* Washington, DC: National Academics Press
- Rittle-Johnson, B., Fyfe, E. F., Loehr, A., & Miller, M. (2015). Beyond numeracy in preschool: Adding patterns to the equation. *Early Childhood Research Quarterly, 31*, 101-112.

- This study is funded in part by grant #2013-26 from the Heising-Simons Foundation, and in part by grant #R305A140126 from the U.S. Department of Education's Institute of Education Sciences..