(One Indicator of) Readiness for College Mathematics: Longitudinal Predictors Among Marginalized Students

Bethany Rittle-Johnson, Rebecca Adler and Kelley Durkin
Vanderbilt University

A roundtable presentation at AERA, April 2023

Figure 1 *An Integrated Theory of Mathematics Achievement from Watts and colleagues (2015)*

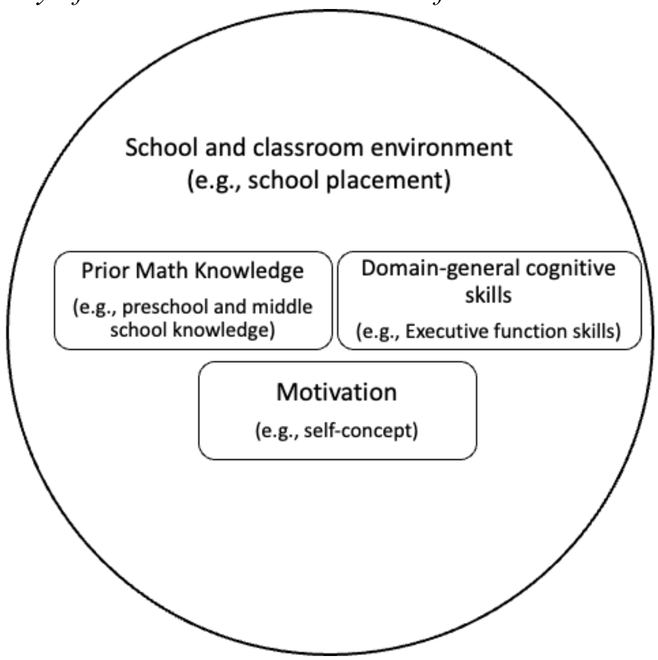
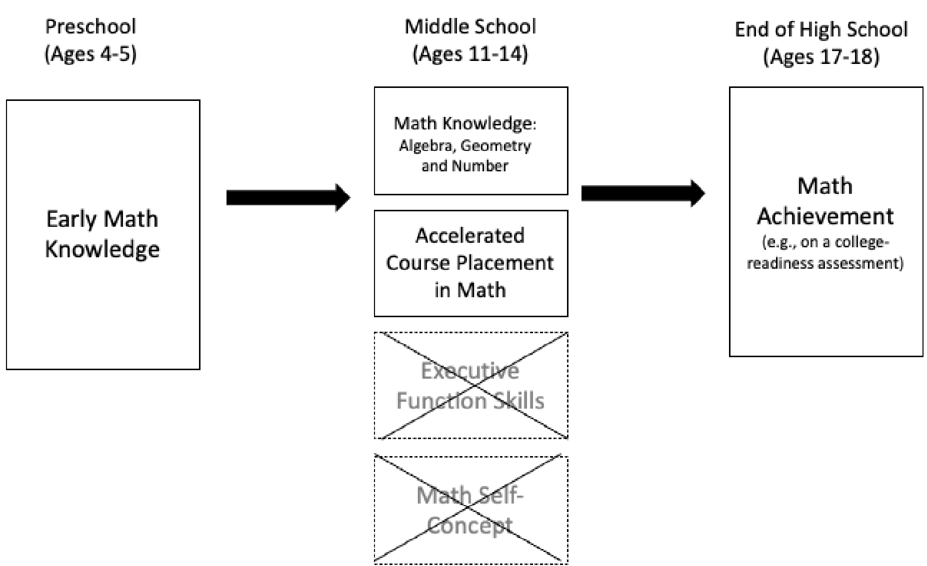


Figure 2 *Our Hypotheses for Current Study with Marginalized Students*



1. **Objective:** To evaluate a range of predictors of scores on a college-readiness assessment for mathematics (the ACT) among students from marginalized backgrounds. The ACT is a widely-used standardized test that provides an overview of high-school students' preparedness for college coursework (ACT, 2022) and is used in some states as a graduation requirement.
2. **Theoretical Framework: An Integrated Theory of Mathematics Achievement**

- Watts and colleagues (2015) identified four classes of factors with strong theoretical and empirical support for impacting math achievement. See Figure 1.
- An integrated theory also needs to acknowledge power and privilege in the U.S. school system (Ladson-Billings & Tate, 1995), and that Black students are often positioned as less capable in math and in school (Nasir & Shah, 2011).
- Figure 2 illustrates our hypotheses.
  - Math self-concept: Unlike findings with predominantly White students, Black students sometimes have positive attitudes (e.g., self-concept) coupled with poor academic achievement (i.e., *attitude-achievement paradoxes*; Mickelson, 1990; Seo et al., 2019).
  - Executive Function (EF): *Fade-Out model* - Individual differences in EF skills may be less relevant by middle school (Stipek & Valentino, 2015).

3. **Participants**: 329 students attending Metro Nashville Public Schools; a majority were female (59%), Black (80%), and from economically-disadvantaged homes (78%).
4. **Measures:**
   a. **Outcome:** Math ACT scores, from school records (a state graduation requirement)
   b. **Preschool Math Knowledge.** A composite measure from scores on the Quantitative Concepts and Applied Problems subtests of the Woodcock Johnson Achievement Battery III and the Research-Based Early Mathematics Assessment (Clements et al., 2008).
   c. **Middle-school Math Knowledge.** The algebra and geometry subtests of the KeyMath 3 Diagnostic Assessment (Connolly, 2007) and the Quantitative Concepts subtest from the Woodcock Johnson Achievement Battery III (measuring number knowledge).
   d. **Math Self-Concept:** Average rating on 9 self-concept items from 2011 Trends in International Mathematics and Science Study Math Attitudes Questionnaire (e.g., "I am good at working out hard math problems").
   e. **Executive Function (EF).** A composite measure using (a) mean accuracy for the mixed trials on Hearts and Flowers task (*cognitive flexibility*; Diamond, 2013), (b) average difference in response time between flower trials and heart trials (*inhibitory control*), and (c) longest span on the backward Corsi block-tapping test (*working memory capacity*; Corsi, 1972).
   f. **Accelerated Math Course Placement:** Whether students were enrolled in a high-school math course in 8th grade (typically Integrated Mathematics I).
   g. **Preschool Domain General Cognitive and Academic Skills (control variables):** Teacher rating of Attention and Self-Regulated Behavior, Narrative Recall, and Reading (Letter-Word).
5. **Procedure**: Data collected (a) beginning of the pre-k school year (mean age = 4.4, *SD* = .3) and (b) when most students were finishing 6th grade (mean age = 12.0, *SD* = .3).

6. **Results**

Table 1 ***Regression Estimates Predicting ACT Math Scores From Preschool and Middle-School Predictors***

	Model 1: Preschool		Model 2: MiddleS		Model 3: All	
	Est.	SE	Est.	SE	Est.	SE
PS Math knowledge	.68**	.21	—	—	.04	.20
PS Attention & Self-regulation	.12	.18	—	—	.07	.15
PS Reading	.01	.18	—	—	.12	.15
PS Narrative Recall	.20	.16	—	—	.19	.14
MS Number knowledge	—	—	.43*	.17	.39*	.17
MS Algebra knowledge	—	—	.59**	.21	.57**	.21
MS Geometry knowledge	—	—	.67***	.17	.61***	.18
MS Math self-concept	—	—	-.05	.13	-.01	.13
MS Executive function	—	—	-.21	.25	-.22	.25
MS Accel. course	—	—	1.5***	.41	1.46***	.41
Controls	Incl.		Incl.		Incl.	

Note. PS = preschool, MS = middle school, Incl. = Included control variables: age, sex, race, whether and when retained a grade level, parents' education level and income level in 10th grade. Bootstrap results also supported indirect effects of PS math through MS math knowledge and accelerated course placement. *$p < .05$. **$p < .01$. ***$p < .001$.

7. **Scientific and scholarly significance**

a) Supports broadening theories of mathematics achievement that typically consider a narrower set of predictors, a more advantaged group of students, researcher-developed and administered measures of achievement, and a shorter developmental time frame.
b) *Early, informal math knowledge* developed outside of formal schooling can predict math achievement through the end of high school. In turn, poor performance in math is a barrier to college education and numerous career paths, and this is especially true for racially- and economically-marginalized students (Lee, 2012). Improving early support for informal math learning for marginalized students, e.g., through enhancing the home math environment, merits increased attention.
c) *Equity in advanced academic opportunities:* An urgent need to address barriers for Black students' equal participation in accelerated math courses, as Black students are half as likely to be enrolled in this opportunity compared to White students (U.S. Department of Education, 2018).
d) *Fade-Out of EF*. Individual differences in EF skills may be less relevant by middle school (Stipek & Valentino, 2015).

e) *Attitude-Achievement Paradox*. Black students may face barriers that reduce the benefits of positive math self-concept for engaging in activities that benefit future math achievement and/or students may resist social stigmas (Seo et al., 2019).
    i) Need to expand integrated theories of math achievement to include indirect influences on children's environment, including systemic, structural factors, such as racism, prejudice, discrimination, and oppression (García Coll et al., 1996)
f) *Limitations:* Current findings may not generalize to marginalized students attending suburban or rural schools, those from middle- and upper-middle class families, or primarily high-achieving students.

Abstract

The goal of the current study was to evaluate a range of predictors of scores on a college-readiness assessment for mathematics among students from marginalized backgrounds, informed by an integrated theory of mathematics achievement proposed by Watts and colleagues (2015). We evaluated preschool and middle-school predictors of math ACT scores in a longitudinal study of predominantly Black students from economically-disadvantaged homes in the United States (n = 329; 80% Black, 59% female). Students' mathematics knowledge at age 4 predicted their math ACT scores in 12th grade (B = .68), controlling for cognitive skills at age 4 and demographic characteristics. Their middle-school mathematics knowledge (number, algebra, and geometry knowledge; *Bs* = .43 - .67), and school placement (high-school math course in 8th grade, B = 1.5) were also unique predictors and mediated the relation between mathematics knowledge at age 4 and math ACT scores. In line with a fade-out model (Stipek & Valentino, 2015), executive function skill in 6th grade was not a unique predictor with prior mathematics knowledge in the model. In line with attitude-achievement paradoxes for Black students, mathematics self-concept in 6th grade was also not a unique predictor. Findings highlight the importance of simultaneously considering multiple factors and systems that influence students' mathematics achievement across preschool to 12th grade and caution in assuming findings with predominantly White, middle-class students generalize to minoritized students.

Project website: https://my.vanderbilt.edu/mathfollowup/

Funding: This research was supported by a National Science Foundation grant (#1760225) to Kelley Durkin and by Heising-Simons Foundation grants (#2013-26 and #2016-104) and Institute of Education Sciences U.S. Department of Education grant (R305A140126) to Dale C. Farran.