Math is for Girls: The Unequal Effects of Text-Messaging to Help Parents Support Early Math Development

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1. Background and Context ("Description of prior research on the subject and/or its intellectual context and/or its policy context.")

Math education has been in the forefront of education policy discussions for over two decades. Interest in math by politicians, policymakers, researchers, and practitioners stems, in part, from the understanding that the economy will depend on jobs in science, technology, engineering, and mathematics (Clements, 2004). While math is increasingly taught in formal early childhood education settings, young children's exposure to math is less prevalent at home. Though parents endorse the notion of supporting math concepts, they tend to focus more on literacy, with some evidence that this preference for literacy is greater in low-income, black, and Hispanic families (Sonnenschein Metzger, and Thompson, 2016). These differences in early home experiences contribute to the achievement gap which affects later-life outcomes.

2. Purpose, Objective, and Research Questions ("Description of the focus of the research, including hypotheses.")

We analyze the effects of 32-week, parent-facing text-message curricula on pre-kindergarten math achievement. The text-messaging program provides parents with small, easy-to-implement activities that leverage everyday routines and household materials. The program is designed to combat common barriers to behavior change identified in behavioral economics. We answer the following research questions:

1. What is the effect of the text-message curricula on pre-kindergarten math achievement
2. Which is more effective, a pure math program or a combination program aimed at developing math, literacy, and social-emotional skills?
3. How do effects vary by gender and student ability?

3. Setting ("Specific description of where the research is taking place")
We fielded the intervention among parents of preschoolers in San Francisco Unified School District, Oakland Unified School District, and Fresno Unified School District during the 2017-2018 school year. We asked parents to participate as part of the pre-kindergarten enrollment process.

4. Population, Participants, and Subjects (Who, how many, key features or characteristics)
Table 1 shows descriptive statistics for student and parent characteristics. Thirty-nine percent of students are Hispanic, 34 percent Asian, 14 percent black, and seven percent white. Students are on average 4.23 years old at enrollment. Nineteen percent of parents do not have a high school degree, 31 percent have a high school degree, and the remainder have at least some college experience. Parents report, on average, an annual household income of $31,003 and being 33.3 years old. Sixty-six percent of parents received the text-messages in English, 21 percent in Spanish, and 13 percent in Cantonese. The analytical sample contains 1,336 students.

5. Intervention ("Specific description of the intervention, including key components of how it is or will be implemented or administered")

The intervention tests a *pure math* program and the *combination* program. Both programs follow a "FACT", "TIP", and "GROWTH" approach to provide information and alleviate behavioral barriers to parenting. On Mondays, parents receive a "FACT" message with general information about a skill. On Wednesday, parents receive a "TIP" messages that follow up with examples of fun and easy-to-implement activities supporting child development. On Fridays, parents receive a "GROWTH" message, which provides encouragement and another activity. The pure math program focuses exclusively on building math related skills. The combination program also covers literacy and social-emotional learning (SEL). Both employ a spiral curriculum.

6. Research Design (Specific description of the research design, including strategies for eliminating sources of bias)

We fielded a randomized control trial to estimate the causal effect of the text-messaging program on math outcomes. We assigned parents into three equal-sized groups in a blocked randomization based on pre-kindergarten center and texting language. The two treatment groups received the pure math or combination program, and the control group received a placebo programs - one text-message with school information every two weeks. It did not provide information on child development or parenting practices.

7. Data Collection and Analysis (Description of methods that will be used in collecting and analyzing data.)

To measure math development, we assessed participating students with the math section of the Brigance Inventory of Early Development III Standardized assessment. We also received student records from the participating districts and collected parent information on the enrollment forms. These data include demographic information, parent knowledge of how to support their child's math, literacy, and SEL, and how often they engage in activities that address those domains.

We estimate the effects of the pure math and combination program with the following model:

$$y_{is} = \alpha + \beta_1 \cdot Combo_{is} + \beta_2 \cdot Math_{is} + \delta \cdot X_{is} + \gamma_s + \varepsilon_{is}, \qquad (1)$$

where y_{is} is the outcome of interest of student, i, in randomization block, s. The outcomes are standardized measures of overall math scores and domain scores. X_{is} is a vector of student and parent characteristics.

8. Findings and Results (Description of main findings with specific details)

Tables 2a, 2b, and 3 show that student and parent covariates are well balanced among treatment arms and that differential attrition is not a problem, respectively. Table 4 shows that, overall, neither the combination program nor the pure math program had a significant effect on math scores. However, the combination program increased girls' assessment scores by 0.156 standard deviations ($p<0.10$). The pure math program, in contrast, had no significant effect on either girls or boys. Table 5 shows the pattern persists when looking individual domains of the assessment.

To understand how program effects varied by student ability and gender, we employ quantile regressions. In order to analyze quantile effects of boys and girls on a common distribution we use translated quantile effects (Bitler, Hoynes, and Domina, 2014) and use the math score distribution of the control group as reference distribution. Figure 1 shows that the effects of the program are concentrated on girls between the 18^{th} and 57^{th} percentile of the reference distribution ($p<0.05$).

9. Conclusions (Description of conclusions, limitations, and recommendations of authors)

This study demonstrates that a text-messaging program for parents based on behavioral economics principals can improve the mathematics development of pre-kindergarteners, with a combination program more effective than a pure math program. Cycling through topics may keep the parents more engaged. If parents struggle on one domain, they may find success in another. Moreover, evidence suggests that these domains are not mutually exclusive (Morris et al., 2013) and even complementary at this age (Purpura, 2011). Our analyses show that the positive effects of the combination program are concentrated on girls with weaker outcomes. We hypothesize that parents may differentially operationalize the texts due to differences in their perceptions of the academic ability and interest of girls and boys (Baroody and Diamond, 2013). Children may also differently react to the prompt to engage in the activities, possibly due to differences in executive functions such as self-regulation (Matthews, Ponitz, and Morrison, 2009). These results suggest that researchers must go beyond the application of broad behavioral economics principals and attempt to understand and incorporate heterogeneity in behavioral barriers and response to those behavioral barriers.

10. References

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Bittler, M., Hoynes, H., and Domina, T. (2014). Experimental evidence on distributional effects of head start. NBER Working Paper No. 20434. Retrieved from https://www.nber.org/papers/w20434.

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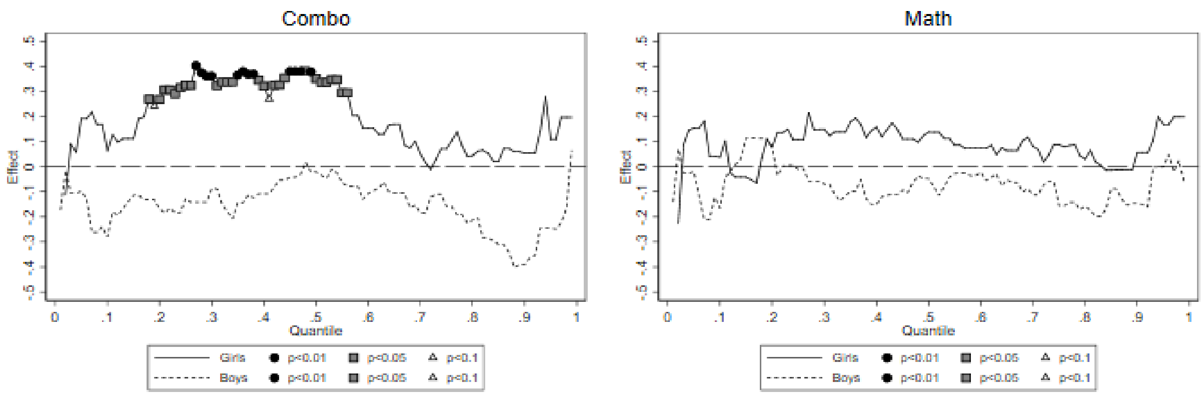

Figure 1: Unconditional Quantile Regressions on Math Outcomes, by Gender

Table 1: Descriptive Statistics

Variables	Mean	Standard Deviation	N
Child Characteristics			
Female	0.495		1331
Age	4.131	0.491	1331
Asian	0.336		1331
Black	0.138		1331
Hispanic	0.392		1331
White	0.065		1331
Other Race/Ethnicity	0.070		1331
Missing Race/Ethnicity Information	0.004		1336
Parent Characteristics			
Less than High School	0.188		756
High School	0.311		756
Some College	0.253		756
Associate's Degree	0.083		756
Bachelor's Degree	0.112		756
Advanced Degree	0.053		756
Missing Education Information	0.434		1336
Age	33.271	6.610	778
Household Income	31002.720	28369.900	698
Hours Worked	20.898	16.977	744
Received Texts in English	0.664		1336
Received Texts in Spanish	0.208		1336
Received Texts in Chinese	0.128		1336
Received Texts in 2015-2016	0.013		1336
Received Texts in 2016-2017	0.170		1336
Parent Baseline Survey Responses on Math Related Items			
Knows How to Build Math Skills	3.845	1.027	756
Counts to 20 or Higher With Child	2.703	0.970	778
Works on Patterns with Child	2.474	1.002	775
Uses Household Objects to Help With Math	2.138	0.975	774
Plays Math Games	2.039	0.957	779

Notes: Parents rated their agreement with a statement that they had knowledge of how to build their child's math skills on a five-point scale (1-Strongly Disagree; 2- Disagree; 3 - Neither Agree nor Disagree; 4 - Agree; 5- Strongly Agree). Parents rated the frequency of engaging in math activities on a four-point scale (1- Not At All; 2- Once or Twice; 3 - Three or Four Times; 4 - More Than Four Times).

Table 2a: Covariate Balance of Student Characteristics

	(1) Combo	(2) Math	F-Test (p-Value)	N
Female	0.015	-0.015	0.747	1336
	(0.039)	(0.039)		
Age	-0.021	0.004	0.394	1336
	(0.019)	(0.020)		
Asian	0.018	0.032	0.375	1336
	(0.023)	(0.023)		
Black	-0.023	-0.012	0.488	1336
	(0.019)	(0.020)		
Hispanic	0.000	-0.013	0.844	1336
	(0.025)	(0.025)		
White	0.015	-0.001	0.626	1336
	(0.018)	(0.014)		
Other	-0.006	-0.001	0.953	1336
	(0.020)	(0.018)		
Missing Race/Ethnicity Information	0.001	-0.003	0.744	1336
	(0.005)	(0.005)		
Fall DRDP				
Approaches To Learning	0.01	0.039	0.83	1298
	(0.068)	(0.070)		
Social and Emotional Development	-0.002	0.011	0.975	1298
	(0.064)	(0.069)		
Language and Literacy Development	0.006	0.041	0.793	1298
	(0.062)	(0.069)		
Cognitive Development	-0.007	0.004	0.982	1298
	(0.064)	(0.070)		
Physical Development and Health	0.016	-0.01	0.918	1298
	(0.063)	(0.069)		

*Notes: Fall DRDP domain averages activities are standardized to have mean zero and standard deviation one. All models include randomization block fixed effects. Standard errors are clustered at the randomization block level. N = 1,336. * indicates p < 0.05*

Table 2b: Covariate Balance of Parent Characteristics

	(1) Combo	(2) Math	F-Test (p-Value)	N
Parent Education				
Less Than High School	0.000	-0.002	0.997	1336
	(0.025)	(0.024)		
High School	-0.031	-0.038	0.354	1336
	(0.026)	(0.028)		
Some College	-0.003	0.019	0.676	1336
	(0.025)	(0.027)		
Associate's Degree	0.036	0.022	0.045	1336
	(0.015)	(0.014)		
Bachelor’s Degree	-0.002	0.000	0.996	1336
	(0.019)	(0.020)		
Master's Degree or Higher	-0.009	0.013	0.234	1336
	(0.011)	(0.013)		
Missing Education Information	0.009	-0.013	0.684	1336
	(0.024)	(0.026)		
Parent Age	-0.737	-0.206	0.549	778
	(0.711)	(0.615)		
Parental Income	1365.652	1800.132	0.733	698
	(2824.145)	(2458.565)		
Hours Worked	-0.704	-0.594	0.934	744
	(2.063)	(1.895)		
Texting Language				
English	-0.01	0.006	0.762	1336
	(0.020)	(0.019)		
Spanish	0.008	0.004	0.894	1336
	(0.017)	(0.015)		
Chinese	0.002	-0.01	0.566	1336
	(0.013)	(0.011)		
Received Texts in 2015-2016	0.005	0.003	0.814	1336
	(0.007)	(0.008)		
Received Texts in 2016-2017	0.019	0.019	0.382	1336
	(0.016)	(0.016)		
Average Parent Baseline Reports of Attitudes and Activities				
Knows How to Support Literacy/Math/Behavior	0.008	0.002	0.997	786
	(0.103)	(0.104)		
Frequency of Literacy Related Activities	-0.017	0.037	0.879	789
	(0.094)	(0.098)		
Frequency of Math Related Activities	-0.025	-0.074	0.766	792
	(0.111)	(0.103)		
Frequency of Behavior Related Activities	0.061	-0.032	0.642	791
	(0.108)	(0.106)		

*Notes: Parent baseline reports of attitudes and activities are domain averages of standardized items. Averages are standardized to have mean zero and standard deviation one. All models include randomization block fixed effects. Standard errors are clustered at the randomization block level. N = 1,336. * indicates p < 0.05*

Table 3: Attrition Balance

	(1)	(2)
	Math Only	Combination
Not Assessed	0.007	-0.032
	(0.024)	(0.023)

Notes: All models include randomization block fixed effects and a comprehensive set of covariates. Standard errors are clustered at the randomization block level. N = 1,842. * indicates $p < 0.05$

Table 4: Effect of Combination and Pure Math Program on Overall Math Achievement

	Mean Math Score				
	Combination		Pure Math	p-Value (Pure Math vs Combination)	N
All Students	0.000		-0.034	0.569	1336
	(0.058)		(0.056)		
Girls	0.156	+	0.015	0.16	661
	(0.083)		(0.099)		
Boys	-0.115		-0.025	0.324	675
	(0.105)		(0.094)		

Notes: + corresponds to p<0.1. Standard errors in parenthesis. Mean math score is the average of the standardized subscores. The average is standardized to have mean zero and standard deviation one. All regression models include randomization block fixed effects and a full set of covariates. Standard errors are clustered on the randomization block level.

Table 5: Effect of Combo and Math Program on Math Assessment Subscores

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	All Students (N=1336)			Girls (N=661)			Boys (N=675)		
	Combo	Math	p-Value (Math vs Combo)	Combo	Math	p-Value (Math vs Combo)	Combo	Math	p-Value (Math vs Combo)
Understands Number Concepts	-0.013	0.003	0.802	0.104	0.078	0.81	-0.086	-0.054	0.743
	(0.066)	(0.058)		(0.106)	(0.113)		(0.112)	(0.095)	
Compares Different Amounts	0.012	-0.059	0.323	0.111	-0.061	0.157	-0.028	0.039	0.558
	(0.073)	(0.077)		(0.105)	(0.124)		(0.133)	(0.115)	
Sorts Objects	-0.083	-0.068	0.814	-0.025	-0.01	0.88	-0.124	-0.133	0.935
	(0.060)	(0.062)		(0.098)	(0.100)		(0.122)	(0.107)	
Matches Quantities with Numerals	0.078	0.002	0.241	0.198 *	0.037	0.095	-0.023	-0.008	0.895
	(0.052)	(0.061)		(0.087)	(0.101)		(0.101)	(0.104)	
Reads Numerals	0.035	0.019	0.816	0.211 *	0.107	0.333	-0.102	-0.046	0.658
	(0.061)	(0.065)		(0.092)	(0.117)		(0.106)	(0.117)	
Solves Word Problems	0.059	-0.005	0.347	0.099	-0.073	0.121	0.014	0.099	0.493
	(0.065)	(0.064)		(0.097)	(0.116)		(0.115)	(0.126)	
Rote Counting	-0.01	-0.02	0.873	0.103	0.052	0.589	-0.108	-0.037	0.522
	(0.074)	(0.059)		(0.112)	(0.110)		(0.121)	(0.094)	
Knows Missing Numerals in Sequence	-0.077	-0.064	0.832	0.089	-0.042	0.234	-0.201 +	-0.002	0.071
	(0.068)	(0.067)		(0.099)	(0.097)		(0.121)	(0.120)	

Notes: +, * correspond to p<0.1 and p<0.05. Standard errors in parenthesis. All values are standardized to have mean zero and standard deviation one. Items of math assessment represent number of tasks correct. Rote Counting corresponds to the highest number counted to. All regression models include randomization block fixed effects and a full set of covariates. Standard errors are clustered on the randomization block level.