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Executive Summary

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BUILDING KNOWLEDGE TO IMPROVE SOCIAL POLICY

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Overview

Early math skills are a strong predictor of later achievement for young children, not only in math, but in other domains as well. Exhibiting strong math skills in elementary school is predictive of later high school completion and college attendance. To that end, the Making Pre-K Count and High 5s studies set out to rigorously assess whether providing high-quality math instruction, aligned across prekindergarten (pre-K) and kindergarten, could lead to long-term gains across a variety of domains for students growing up in low-income communities in New York City.

In Making Pre-K Count, pre-K programs were randomly assigned to receive an evidence-based early math curriculum (Building Blocks) and associated professional development or to a pre-K-as-usual control condition. Pre-K in New York City changed rapidly during the study, with teachers overall conducting substantially more math than had previously been documented — a factor that may have played a role in the lack of impacts from Making Pre-K Count on children's math learning at the end of the pre-K year. In the High 5s study, students who had been in Making Pre-K Count program classrooms in pre-K were individually randomly assigned within schools in the kindergarten year to supplemental small-group math clubs, which took place outside of regular instructional time, or to a business-as-usual kindergarten experience. A companion report describes the High 5s program in more detail. This report focuses on the effects in kindergarten of the two math programs.

Key Findings

- **Making Pre-K Count:** At the end of kindergarten, there was a small, positive, but not consistently statistically significant effect for the Making Pre-K Count program on one of two measures of math skills, a measure that is more sensitive to children's skill levels than the more global test used in pre-K and kindergarten. Making Pre-K Count led to positive impacts on children's attitudes toward math at the end of kindergarten and to about two months' greater growth in kindergartners' working memory skills.

- **Making Pre-K Count plus High 5s kindergarten supplement:** Two years of aligned, enhanced math experiences led to positive impacts on the more sensitive measure of children's math skills, both above and beyond Making Pre-K Count alone (equivalent to 2.5 months' growth) and compared with no math enrichment in pre-K and kindergarten (equivalent to 4.2 months' growth); effects were positive but not statistically significant on the more global measure. The effect of two years of enhanced math translates into closing more than a quarter of the achievement gap between low-income children and their higher-income peers at the end of kindergarten. Children who were offered two years of math enrichment also had more positive attitudes toward math than children with no enrichment.

These findings suggest that early enriched math instruction, particularly when aligned across years, can have a positive effect on children's math skills, math attitudes, and working memory. The amount of math already in place was associated with the magnitude of the estimated effects of these programs. In addition, the sensitivity of the math measures used in the study may have played a role in how well each assessed math skills. The studies will continue to follow children into third grade to better understand the long-term effects of these early math programs.

Preface

Making Pre-K Count and High 5s were developed in a partnership between the Robin Hood Foundation, the Overdeck Family Foundation, the Heising-Simons Foundation, and other funders and MDRC to tackle the question of how to improve the quality of early instruction in a meaningful and long-lasting way, and on a large scale. The approach consists of an evidence-based preschool math curriculum, with training and coaching for teachers, followed in kindergarten by small math clubs designed to align pre-K and kindergarten in content and pedagogy. The study asked important questions about scale, instructional alignment from year to year, and the power of math to change children's outcomes across multiple domains.

The findings show that the preschool and kindergarten math programs tested in this study can be widely implemented and that they can have a positive impact on children's outcomes compared with business as usual — even at a time when New York City was investing heavily in pre-K, and business as usual involved an emphasis on math. The combined effect of Making Pre-K Count and High 5s is meaningful and potentially trajectory-changing, comparable to closing more than a quarter of the achievement gap between low-income children and their higher-income peers in kindergarten. And both programs individually make a difference for children's outcomes, although the effects of the preschool math curriculum may have been tamped down by a combination of how much math was already being conducted in preschool and the measures available for that age group.

These results come at a time when investments in preschool are being hotly debated within the field. Some large, highly publicized studies have found few impacts of preschool when provided across children at all income levels, while other studies have calculated positive effects and large returns on the investment. As the debate rages, localities continue to move forward with funding and expanding preschool for their constituents. This study speaks to both the debate and those funding and implementing preschool by asking not whether preschool works but how the quality of preschool can be strengthened to ensure positive, meaningful experiences for children.

The Making Pre-K Count and High 5s findings suggest that aligned, developmentally informed math instruction bolsters children's early learning experiences. The study will continue to follow children into elementary school to explore whether these effects are maintained as children move into new instructional environments.

Gordon L. Berlin
President, MDRC

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The Making Pre-K Count and High 5s studies were a joint effort with many collaborators. We thank the teachers, facilitators, and site administrators who helped make this study possible. Our thanks also to the children, families, and teachers who gave so generously of their time and cooperation, without whom the study would not have been possible.

Both programs could not have been run without the dedicated support and hard work of our partners at Bank Street College, who provided coaching, facilitation, and supervision across Making Pre-K Count and High 5s. We thank Katherine Baldwin and Josh Thomases for their guidance, thoughtful partnership, and review of the report. We also thank the current and former leadership at the New York City Department of Education's Division of Early Childhood Education and the Division of Child Care and Head Start at the Administration for Children's Services, who worked with us as this study unfolded. Additionally, this work could not have been possible without the deep dedication of the developers of Building Blocks, Drs. Doug Clements and Julie Sarama, who helped us support Building Blocks implementation and conceptualize the High 5s program, and who provided ongoing consultation. We also thank the teams of Building Blocks and New York City-based trainers, who trained teachers, and Anna Erickson and Kristi Hanby at the University of Michigan, who helped develop the High 5s intervention and training.

The execution of this study was made possible by our research partners at RTI International, including Jean Lennon, Jennifer Keeney, Joe Simpson, and the many dedicated data collectors. We also extend our appreciation to the steering committees for Making Pre-K Count and High 5s and our academic partners, Peg Burchinal of the University of North Carolina; Greg Duncan of the University of California, Irvine; Dale Farran of Vanderbilt University; and Christina Weiland of the University of Michigan.

The project benefited tremendously from the ongoing support and commitment of the Robin Hood Foundation, the Heising-Simons Foundation, the Overdeck Family Foundation, and the Richard W. Goldman Family Foundation.

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The Authors

Executive Summary

Recent research suggests that early math proficiency is one of the strongest predictors of later achievement for young children, not only in math, but in other domains as well.[1] Enhancing early math instruction, therefore, is a promising area for supporting low-income children's long-term outcomes. Moreover, aligning instruction from year to year may help sustain or even enhance the impacts from early math enrichment.[2] To that end, the Making Pre-K Count and High 5s studies set out to rigorously assess whether providing aligned, high-quality math instruction during prekindergarten (pre-K) and kindergarten could provide a critical boost that would lead to long-term achievement gains across a variety of domains.

Specifically, the studies assessed the impact of two programs on short- and longer-term child outcomes, including math, language, and executive function, for students growing up in low-income communities in New York City.[3] In the Making Pre-K Count study, pre-K programs in both public schools and community-based organizations were randomly assigned either to receive an evidence-based early math curriculum (Building Blocks) and associated professional development or to a pre-K-as-usual control condition. In the High 5s study, students who had been in Making Pre-K Count program classrooms in pre-K (in the public school sites) were individually randomly assigned within schools to small-group supplemental math clubs, which met outside of regular instructional time, or to a business-as-usual kindergarten experience. High 5s was designed to sustain the gains from the pre-K program and build on the same developmental trajectories and approach to learning that formed the basis of the Building Blocks program.

The studies were developed as part of the Robin Hood Early Childhood Research Initiative, which was established to identify and rigorously test promising early childhood interventions. That initiative is a partnership between Robin Hood, one of New York City's leading antipoverty organizations, and MDRC, a nonprofit, nonpartisan education and social policy

[1]Greg J. Duncan, Chantelle J. Dowsett, Amy Claessens, Katherine Magnuson, Aletha C. Huston, Pamela Klebanov, Linda S. Pagani, Leon Feinstein, Mimi Engel, and Jeanne Brooks-Gunn, "School Readiness and Later Achievement," *Developmental Psychology* 43, no. 6 (2007): 1428-1446; Greg J. Duncan and Katherine J. Magnuson, "The Nature and Impact of Early Skills, Attention, and Behavior" (paper presentation, Russell Sage Foundation Conference on Social Inequality and Educational Outcomes, New York City, 2009).

[2]Valerie E. Lee and Susanna Loeb, "Where Do Head Start Attendees End Up? One Reason Why Preschool Effects Fade Out," *Educational Evaluation and Policy Analysis* 17, no. 1 (1995): 62-82.

[3]Executive function consists of the set of skills underlying children's ability to regulate themselves, their behavior, and their emotions. In early childhood, executive function skills include the ability to stop a primary response in favor of a more appropriate response (inhibitory control), the ability to shift attention and thinking from one rule or topic to another (cognitive flexibility), and the ability to manipulate small amounts of information (working memory).

research organization. Its flagship project, Making Pre-K Count and High 5s, was conducted in collaboration with Bank Street College of Education and RTI International and supported with lead funding from the Heising-Simons Foundation, the Overdeck Family Foundation, and the Richard W. Goldman Family Foundation. This is one of four reports based on this set of studies.

Findings from the end of the pre-K period show that Making Pre-K Count was implemented with fidelity to the program model.[4] The program had modest, positive impacts on the amount and quality of teacher math instruction at the end of the pre-K year. Program teachers conducted an additional 12 minutes of math per morning, although, notably, there was already a large amount of math — 35 minutes per morning — taking place in New York City pre-K classrooms. Despite the impacts on teachers' math practices, and perhaps because of the relatively high degree of math in pre-K-as-usual classrooms, there were no consistent effects on child outcomes at the end of pre-K. High 5s was also implemented with strong fidelity to the program model (as discussed in a companion report being published concurrently).[5]

This report is designed to explore the impact of Making Pre-K Count and High 5s on children's math skills, language skills, executive function, and attitudes toward math at the end of kindergarten. The main findings for outcomes at the end of kindergarten are as follows:

- **Making Pre-K Count:** At the end of kindergarten, small, positive, but not consistently statistically significant impacts were found on one of two measures of math skills for the Making Pre-K Count program. Making Pre-K Count led to positive impacts on children's attitudes toward math and to about two months' greater growth in kindergartners' working memory skills compared with the skills of kindergartners who did not receive enriched math in pre-K. Making Pre-K Count did not have statistically significant impacts on children's language or inhibitory control skills.

- **Making Pre-K Count plus High 5s kindergarten supplement:** At the end of kindergarten, two years of aligned, enhanced math led to positive and statistically significant impacts on one of two measures of math skills for students, both above and beyond Making Pre-K Count alone (equivalent to 2.5 months of growth) and compared with no math enrichment in either pre-K or kindergarten (equivalent to 4.2 months of growth). The effect of two years of enhanced math experiences translates into closing more than a quarter of the

[4]Pamela A. Morris, Shira K. Mattera, and Michelle F. Maier, *Making Pre-K Count: Improving Math Instruction in New York City* (New York: MDRC, 2016).

[5]Robin Jacob, Anna Erickson, and Shira K. Mattera, *Launching Kindergarten Math Clubs: The Implementation of High 5s in New York City* (New York: MDRC, 2018).

achievement gap between low-income children and their higher-income peers at the end of kindergarten.[6] Children who were offered two years of enhanced math experiences had more positive attitudes toward math than children with no enrichment. However, the programs did not have statistically significant impacts on children's language or executive function skills, or on the global measure of math skills that was likely influenced by children's language skills.

The size of the estimated effects from the pre-K program may have been due in part to the large amount of math already taking place in New York City and the sensitivity of the measures used to assess children's math skills. One of the math measures used in kindergarten was more sensitive to children's skill levels than the more global test used in pre-K and kindergarten. The sensitivity of that measure was due to a number of factors, including its depth and breadth of math skill assessment; it was not due to overalignment with the math programs.

The Math Programs

The Making Pre-K Count program provided pre-K teachers in New York City with a high-quality math curriculum (Building Blocks) and ongoing teacher training and coaching over two years. Building Blocks is a 30-week, evidence-based curriculum designed to take into account children's natural developmental progression in math skills.[7] Teachers received 11 days of training over the two years and met with coaches two to four times a month. In previous studies, Building Blocks has had positive impacts on teachers' math practices and children's preschool math outcomes in locales with little math instruction in place.[8]

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[6]The effect sizes in this study are standardized measures of the difference in outcomes at the end of the kindergarten year for the control and program groups. The effect sizes were compared with standardized measures of the difference in outcomes at the end of kindergarten for children in the 90th income percentile and children in the 10th income percentile in the Early Childhood Longitudinal Study (ECLS) conducted in the 2010-2011 year (as described in Sean F. Reardon and Ximena A. Portilla, "Recent Trends in Income, Racial, and Ethnic School Readiness Gaps at Kindergarten Entry," *AERA Open* 2, no. 3 [2016]). In spring 2011, the income achievement gap was equivalent to 1.046 standardized units. The effect size of two years of enhanced math experiences in this study (0.30) is equivalent to 29 percent of that gap. The income achievement gap can also be calculated by comparing low-income children with their middle-income peers (a gap equivalent to 0.556 at kindergarten entry in 2010). The effect found here is equivalent to closing over half of the low-income–middle-income achievement gap.

[7]Douglas H. Clements and Julie Sarama, *Building Blocks: Teacher's Edition* (Columbus, OH: McGraw-Hill, 2013).

[8]Douglas H. Clements and Julie Sarama, "Effects of a Preschool Mathematics Curriculum: Summative Research on the Building Blocks Project," *Journal for Research in Mathematics Education* 38, no. 2 (2007): 136-163; Douglas H. Clements and Julie Sarama, "Experimental Evaluation of the Effects of a Research-Based Preschool Mathematics Curriculum," *American Educational Research Journal* 45, no. 2 (2008): 443-493; Kerry G. Hofer, Mark W. Lipsey, Nianbo Dong, and Dale C. Farran, "Results of the Early Math Project: Scale-Up Cross-Site Results," working paper (Nashville: Peabody Research Institute, Vanderbilt University, 2013).

The High 5s kindergarten supplement was developed to offer math enrichment in kindergarten to children who had received Making Pre-K Count in pre-K. A number of studies have shown that early impacts of preschool interventions fade out over time as children move into elementary school.[9] One hypothesis for this phenomenon is that the instruction that children receive in kindergarten and beyond is not well aligned, in instructional content or pedagogical approach, with the instruction they received in preschool.[10] Therefore, the High 5s program was designed to align with both the content and format of the activities students had been exposed to in pre-K. The program was developed by Robin Jacob and staff members at the University of Michigan with support from the developers of Building Blocks. Bank Street College of Education hired, trained, and supervised the facilitators, and MDRC provided ongoing operational support to both the participating schools and to Bank Street. The High 5s supplement paired three to four children with one facilitator for math clubs that met three times a week for 30 minutes each. The clubs offered math enrichment in a setting outside of regular classroom instruction, using engaging, developmentally appropriate activities. A companion report attests that the clubs were implemented well, with fidelity to the curricular materials.

Impacts of Early Math Programs on Kindergarten Outcomes

These two studies set out to explore whether providing young children with enhanced math instruction in early childhood could lead to learning gains that would translate into a sustained achievement boost across a variety of domains. As shown in Figure ES.1, analyses examine impacts at the end of kindergarten for three different comparisons:

- Comparison 1: Making Pre-K Count in pre-K versus no math enrichment
- Comparison 2: Making Pre-K Count plus the High 5s kindergarten supplement versus Making Pre-K Count only
- Comparison 3: Making Pre-K Count plus the High 5s kindergarten supplement versus no math enrichment in either pre-K or kindergarten

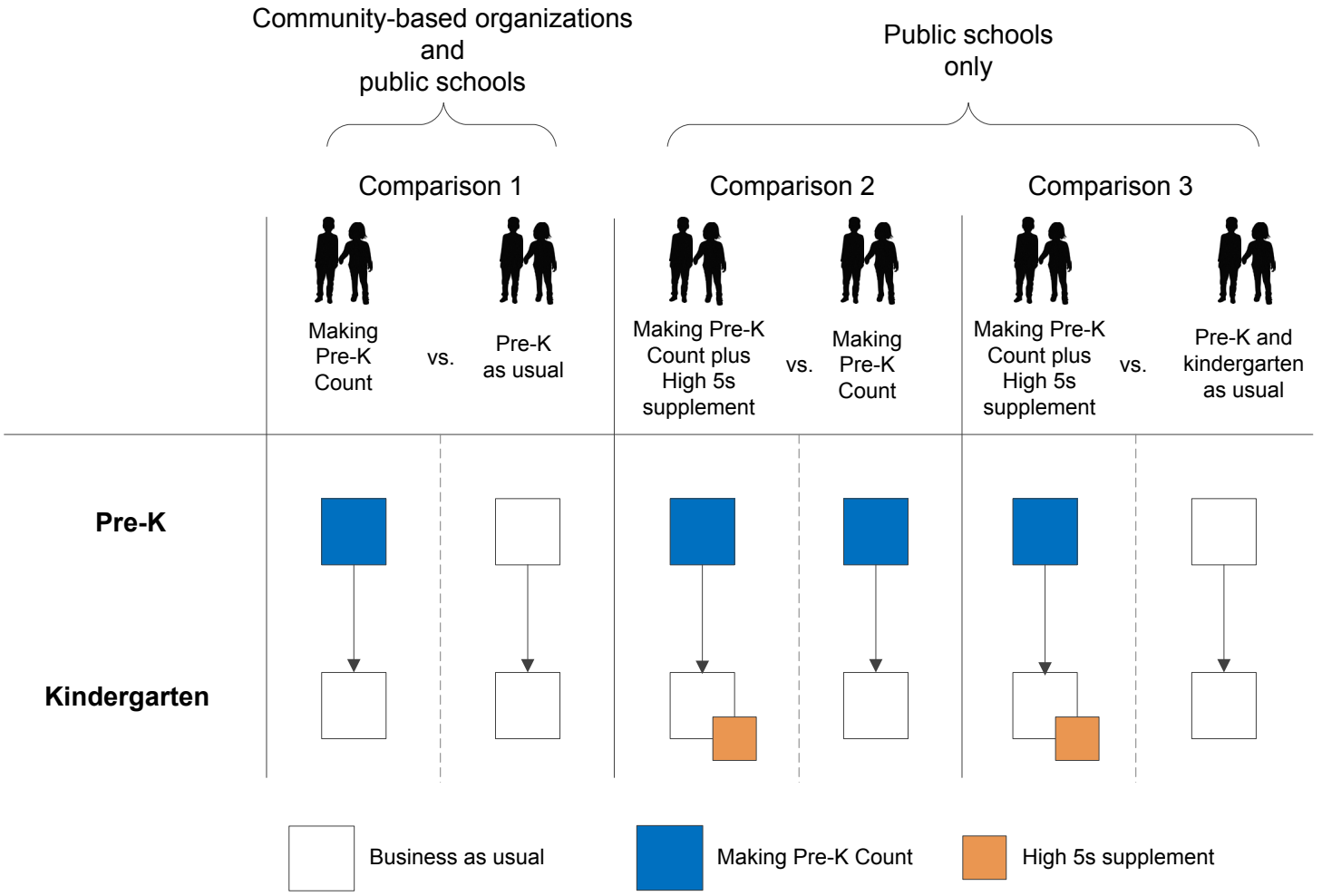
Math was assessed directly through two measures (the Research-Based Early Math Assessment–Kindergarten, or REMA-K, and the Woodcock-Johnson Applied Problems), which are described in greater detail in Box ES.1. Math attitudes were measured with an MDRC-developed question that drew on prior work: a show card displaying a range of five sad (1) to smiling (5) faces to describe how happy or unhappy math made children feel. Children's

[9]Mark W. Lipsey, Kerry G. Hofer, Nianbo Dong, Dale C. Farran, and Carol Bilbrey, *Evaluation of the Tennessee Voluntary Prekindergarten Program: Kindergarten and First Grade Follow-Up Results from the Randomized Control Design* (Nashville: Peabody Research Institute, Vanderbilt University, 2013).

[10]Lee and Loeb, "Where Do Head Start Attendees End Up?"

Figure ES.1

What Are the Comparisons?
Impacts Measured at the End of Kindergarten



Box ES.1

Measuring Children's Kindergarten Math Skills in Making Pre-K Count and High 5s

Two measures were used to assess children's math skills in these studies:

- The Research-Based Early Math Assessment–Kindergarten (**REMA-K**) is a direct assessment used in kindergarten that measures thinking and learning related to a child's developmental progression along research-based mathematical learning trajectories. It was developed by the authors of the Building Blocks curriculum. These studies used a modified version of the assessment with a total of 48 items from the bank of over 100 items that constitute the full REMA.*
- The **Woodcock-Johnson Applied Problems** subscale, used in kindergarten and pre-K, is a standardized assessment of mathematical thinking for ages 2 through 90 that has been used widely in other studies of math interventions.†

What is the difference between these two measures? The REMA-K may be a more sensitive measure than the Woodcock-Johnson for a number of reasons. First, the REMA-K is a lengthier test that includes more items with the intention of assessing granular information about children's abilities in each mathematical skill, such as numbers or geometry, at each level of that skill. For example, the REMA-K includes nine questions about geometry or geometric measurement, while the Woodcock-Johnson has only three geometry items. Second, most items on the REMA-K assess only one specific skill at a time. Many of the Woodcock-Johnson items assess a mix of math content areas within one item. For example, one item on the Woodcock-Johnson asks children both to add and to understand coin value. Finally, the Woodcock-Johnson draws upon children's language skills in addition to math, as exemplified by items that ask children to count a certain animal in an array of animals. A child with strong language and math skills will do better on this test than one with commensurate math skills but for whom language and vocabulary may be lagging slightly.

Although the REMA-K was developed by the creators of Building Blocks, Douglas H. Clements and Julie Sarama, analyses suggest that the measure is not closely aligned with either of the math programs tested in this study. Ten percent of the items on the REMA-K (5 out of 48) look substantially similar in questions and materials to the types of activities to which children were exposed in Building Blocks or High 5s. (The High 5s program was not built off of Building Blocks activities and did not substantially align with Building Blocks.) Sensitivity analyses were conducted estimating program impacts on the REMA-K without the five more-aligned items; the magnitude and statistical significance of the effects stayed substantively the same without those items.

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*Douglas H. Clements, Julie Sarama, and Xiufeng H. Liu, "Development of a Measure of Early Mathematics Achievement Using the Rasch Model: The Research-Based Early Maths Assessment," *Educational Psychology* 28, no. 4 (2008): 457-482.

†Richard W. Woodcock, Kevin S. McGrew, and Nancy Mather, *Woodcock-Johnson III Tests of Achievement* (Itasca, IL: Riverside, 2001).

language ability was measured using the Receptive One-Word Picture Vocabulary Test (ROWPVT-4), a standardized assessment of children's receptive vocabulary, or their ability to understand spoken language.[11] Executive function was measured two ways: with Hearts and Flowers, a computerized task that measures inhibitory control (the ability to stop an automatic response), and the Corsi Blocks task (backward span), which assesses short-term memory.[12]

Figure ES.2 presents the effects from each of these comparisons on children's math skills, attitudes toward math, language ability, and executive function in kindergarten.

- **One year of enhanced math in pre-K (Making Pre-K Count in pre-K) led to a small, positive, but not consistently statistically significant effect on one out of two measures of children's kindergarten math skills.**

The magnitude of the effect does not appear to be sensitive to how the measure or sample was specified, with impact estimates ranging in size from 0.08 to 0.12 standard deviations across different specifications. The estimates are statistically significant in three out of five specifications. These estimated effects are smaller than what has been found on a version of the REMA previously; in an earlier study of Building Blocks that took place in a similar context, researchers found an effect size of 0.19 standard deviations on the REMA at the end of kindergarten.[13] There was no effect on the Woodcock-Johnson Applied Problems, which is thought to be a less sensitive measure of children's math skills.

Pre-K enhanced math instruction led to more positive attitudes toward math and stronger working memory skills at the end of kindergarten than were found among children who had received pre-K as usual, equivalent to about two additional months of growth in working memory skills. The program had no impact on children's receptive language at the end of kindergarten.

High 5s math clubs took place in public school sites only. It was therefore important to examine the effect of Making Pre-K Count separately for those sites. In public school sites (Appendix Table G.1 in the full report), Making Pre-K Count had a positive effect on the more sensitive measure of children's kindergarten math skills, equal to nearly two months of

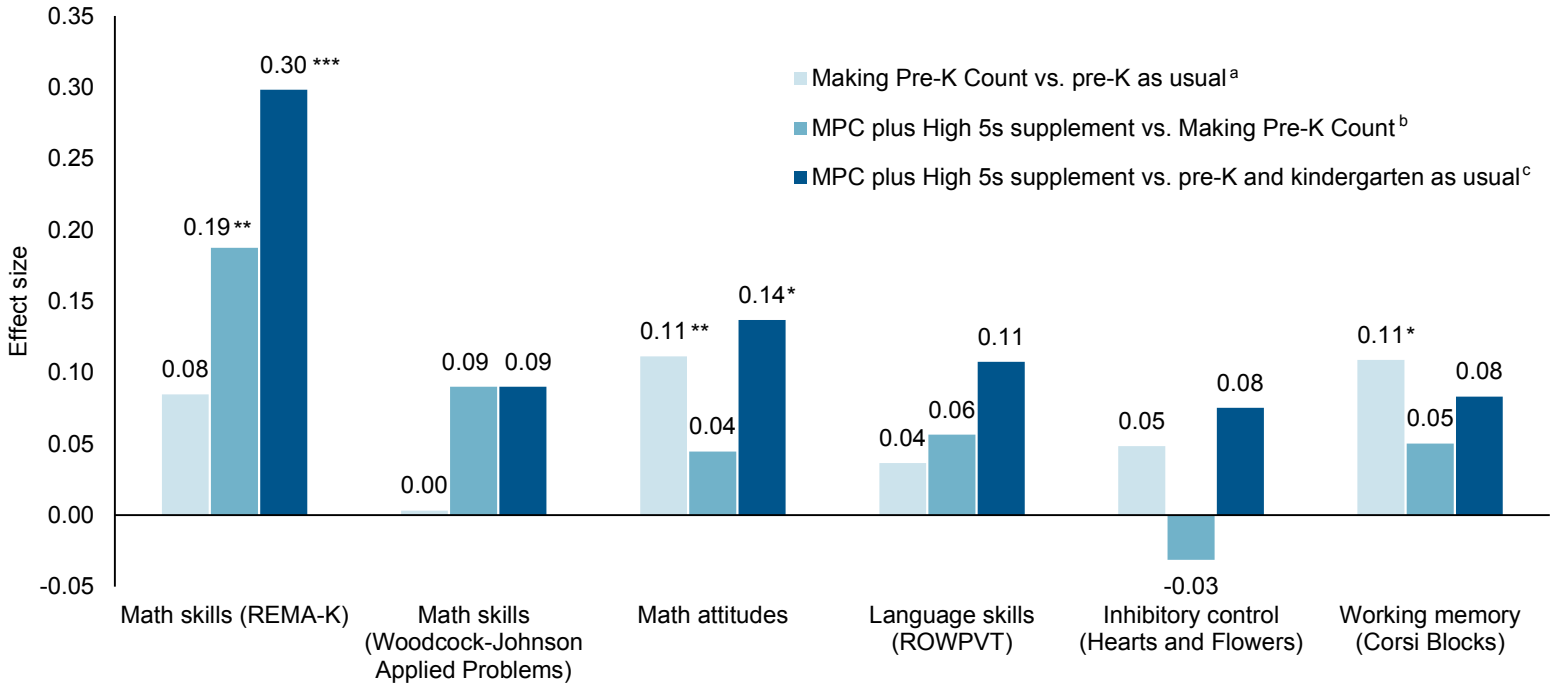
[11]Nancy A. Martin and Rick Brownell, *Receptive One-Word Picture Vocabulary Test*, 4th ed. (Novato, CA: Academic Therapy Publications, 2011).

[12]Andy Wright and Adele Diamond, "An Effect of Inhibitory Load in Children While Keeping Working Memory Load Constant," *Frontiers in Psychology* 5 (2014); Philip Michael Corsi, "Human Memory and the Medial Temporal Region of the Brain," PhD diss. (Montreal: McGill University, 1972); Muriel Deutsch Lezak, *Neuropsychological Assessment* (New York: Oxford University Press, 1983).

[13]Douglas H. Clements, Julie Sarama, Carolyn Layzer, Fatih Unlu, Carrie Germeroth, and Lily Fesler, "Effects on Mathematics and Executive Function Learning of an Early Mathematics Curriculum Synthesized with Scaffolded Play Designed to Promote Self-Regulation Versus the Mathematics Curriculum Alone" (unpublished paper, 2016), PDF.

Figure ES.2

Impacts in the Spring of the Kindergarten Year



SOURCE: MDRC calculations based on the direct child assessments administered in spring 2016.

NOTES: Statistical significance levels are indicated as follows: *** = 1 percent; ** = 5 percent; * = 10 percent.

Effect size is calculated by dividing the impact of the program (the difference between the means for the program group and the control group) by the standard deviation for the control group.

[a]The Making Pre-K Count (MPC) program group received Making Pre-K Count in pre-K. The pre-K-as-usual control group did not receive math enrichment.

[b]The MPC plus High 5s supplement group received Making Pre-K Count in pre-K and High 5s in kindergarten. The Making Pre-K Count group received only Making Pre-K Count in pre-K. Both groups consist of public school children only.

[c]The MPC plus High 5s supplement group received Making Pre-K Count in pre-K and High 5s in kindergarten. The pre-K-and-kindergarten-as-usual control group did not receive math enrichment. Both groups consist of public school children only.

additional learning (effect size = 0.13 standard deviations), as measured at the end of kindergarten. The program also had a positive impact on children's math attitudes in kindergarten at public school sites. Therefore, High 5s math clubs took place on top of a documented impact of the Making Pre-K Count program on both math skills and math attitudes.

- **Compared with enhanced pre-K math only (Making Pre-K Count alone), the addition of the High 5s kindergarten supplement led to positive, statistically significant impacts on one of two measures of kindergarten math skills.**

These impacts for the High 5s kindergarten supplement translate into two and a half additional months of math learning (effect size = 0.19 standard deviations) on the REMA-K. There was no effect of the program on the Woodcock-Johnson Applied Problems, a global measure of math. There were no effects of the kindergarten math clubs on children's language, math attitudes, or executive function above and beyond the effects of Making Pre-K Count.

- **Two years of enhanced math instruction (Making Pre-K Count plus High 5s) led to positive impacts on one of two measures of children's math skills at the end of kindergarten, compared with no enhanced math instruction in pre-K or kindergarten.**

Two years of enhanced math experiences led to 4.2 additional months of math learning compared with business-as-usual math instruction in pre-K and kindergarten (effect size = 0.30 standard deviations) on the REMA-K. There were positive but not statistically significant effects on the Woodcock-Johnson assessment. The two years of math programming also led to more positive attitudes toward math compared with business-as-usual pre-K and kindergarten.

Contributing Factors

Some of the findings from this newest wave of analyses are consistent with expectations about the benefits of two years of math enrichment on children's math learning and attitudes. Findings from the enhanced pre-K math instruction, however, are inconsistent across pre-K and kindergarten, and the pattern of findings does not match prior expectations or most of the previous studies of the Building Blocks program. Prior Building Blocks studies have shown positive effects on pre-K teachers' math instruction, which have led to positive impacts on children's math skills at the end of pre-K (in the range of 0.47 to 1.47 standard deviations), with effects persisting — albeit with some fade-out in magnitude — into kindergarten.[14] In this study, the

[14]Clements and Sarama, "Effects of a Preschool Mathematics Curriculum"; Clements and Sarama, "Experimental Evaluation of the Effects of a Research-Based Preschool Mathematics Curriculum"; Hofer, Lipsey, Dong, and Farran, "Results of the Early Math Project."

positive effects on teachers' math practices in Making Pre-K Count did not lead to impacts on children's skills at the end of pre-K (with the exception of a small, positive impact on children's inhibitory control skills). Yet impacts of the program on both math attitudes and working memory skills emerged at the end of kindergarten. A number of differences between this study and prior studies suggest factors that may have contributed to this lack of alignment in findings:

- **Amount of math in the pre-K environment.** The small impacts that resulted from the pre-K program appear to have been due in part to the large amount of math instruction already occurring in New York City's pre-K programs. In earlier studies of Building Blocks, less math instruction took place in control group preschools — as low as 12 to 16 minutes per morning. Therefore, an additional 5 to 10 minutes of math may have added substantially more and different math content for children. In Making Pre-K Count, teachers in pre-K-as-usual classrooms were engaging in 35 minutes of math per morning on average. In this kind of environment, with teachers engaging in so much math content, even 12 additional minutes of math may not have substantially changed children's math experience. Exploratory analyses provide some support for this hypothesis; in Making Pre-K Count, impacts on children's pre-K math skills were larger in places where less math was taking place in pre-K-as-usual classrooms.

- **Measurement.** Math skills in kindergarten (and in prior Building Blocks studies) were measured using the REMA.[15] As discussed in Box ES.1, analyses demonstrate that the REMA-K is not highly aligned with the Building Blocks curriculum. Rather, the REMA-K proved to be a more sensitive measure of children's math skills, capturing more detailed information about each skill level, than either the Woodcock-Johnson assessment or the other measure of children's math skills used in pre-K. The more limited sensitivity in the pre-K measures may have contributed to the lack of measurable effects and therefore the lack of consistency with prior studies or with the kindergarten impacts.

- **Sample.** The sample in Making Pre-K Count also differed from study samples in prior Building Blocks studies. The Making Pre-K Count sample was more heavily Hispanic and entered pre-K with higher cognitive scores on

[15]Douglas H. Clements, Julie Sarama, Mary Elaine Spitler, Alissa A. Lange, and Christopher B. Wolfe, "Mathematics Learned by Young Children in an Intervention Based on Learning Trajectories: A Large-Scale Cluster Randomized Trial," *Journal for Research in Mathematics Education* 42, no. 2 (2011): 127-166; Douglas H. Clements, Julie Sarama, Carolyn Layzer, Fatih Unlu, Christopher B. Wolfe, Mary Elaine Spitler, and Daniel Weiss, "Effects of TRIAD on Mathematics Achievement: Long-Term Impacts" (paper presentation, Society for Research on Educational Effectiveness Spring Conference, Washington, DC, March 2-5, 2016).

average. While there was little evidence that either of these sample characteristics directly led to differentially small impacts, it is still possible that some combination of sample characteristics play a role in how the findings from this study align with prior work.

Implications

To date, the findings from these studies suggest a number of takeaways:

- **Early math enrichment appears to support children's math skills at the end of kindergarten.**

Two years of math enrichment via both Making Pre-K Count and High 5s had an impact equivalent to over four months of additional growth compared with pre-K and kindergarten as usual. This is equivalent to closing more than a quarter of the achievement gap between low-income children and their higher-income peers at the end of kindergarten. There was also some (although more limited) evidence that Making Pre-K Count alone had a small, positive impact on children's math skills, especially in the public school programs. The math enrichment children were offered in kindergarten via High 5s led to effects on math skills equivalent to about two and a half months over and above the impacts of Making Pre-K Count alone.

- **Sustained, aligned instruction in mathematics over multiple years is potentially important for children's math development.**

The alignment between pre-K and kindergarten math instruction may have been one factor that contributed to the impacts of the High 5s program. Small-group enrichment programs, like High 5s, may be one short-term approach to improving alignment in both content and pedagogy between early elementary school and what many children experience in pre-K.

- **Early math enrichment may have positive implications in domains beyond math.**

At the outset of this study, short-term improvements in math were hypothesized to spill over into other domains of children's learning, like executive function. Findings from this study demonstrate that a math intervention may have effects on other domains, such as working memory. These effects hold the potential for longer-term impacts, because executive function is hypothesized to be important for supporting longer-term effects and reducing fade-out of early childhood programs.[16]

[16]Susan E. Gathercole, Susan J. Pickering, Camilla Knight, and Zoe Stegmann, "Working Memory Skills and Educational Attainment: Evidence from National Curriculum Assessments at 7 and 14 Years of Age," (continued)

- **Places where a limited amount of math is being taught may benefit more from early math programs.**

Despite taking place in a shifting pre-K environment where the amount of math was growing from year to year, Making Pre-K Count led to an additional 12 minutes of math instruction per morning. Unlike prior studies, however, these 12 minutes of math did not lead to better outcomes for children at the end of pre-K. One of the reasons for the limited impacts observed at the end of pre-K may have been the relatively high amount of math taking place in pre-K-as-usual classrooms. This suggests that more high-quality math may matter most in an environment with very little math to begin with.

What's Next

Many questions remain about which impacts will be sustained into later elementary school for the children who participated in these two programs. The Making Pre-K Count and High 5s studies will uniquely be able to track the trajectory of effects across time and across domains. The studies will continue to follow children into third grade to better understand the long-term effects of these early enhanced math programs. These data will also help inform the field about the longitudinal relationships between early math measures and later outcomes for children.

These studies also raise questions about the timing of enhanced math experiences and the relative benefits of pre-K and kindergarten enrichment. It is unclear what the effect of kindergarten enrichment alone (without enhanced pre-K instruction) would have been or to what extent the enhanced math instruction in pre-K contributed to effects observed at the end of kindergarten.

At the same time, High 5s was a new program, and its theory of change is not yet well understood. Specifically, it is unclear whether the added math time, the wider math content, the instructional climate, or the individualized instruction — or some combination of the four — contributed to the impacts on children's math skills. Given the potential strength of High 5s, it is worth considering how it could serve as a model for integrating more small group work and hands-on learning opportunities into kindergarten math instruction in the classroom. Replication of the program with various adaptations (for example, in contexts where children do not enter kindergarten with a strong math background, or as a "push-in" or "pull-out" program slotted into the school day and run by paraprofessionals) could help identify the most important components of the program and identify contexts in which the program is most likely to be effective.

Applied Cognitive Psychology 18 (2004): 1-16; Megan M. McClelland, Alan C. Acock, Andrea Piccinin, Sally Ann Rhea, and Michael C. Stallings, "Relations Between Preschool Attention Span-Persistence and Age 25 Educational Outcomes," *Early Child Research Quarterly* 28, no. 2 (2013): 314-324; Jens Ludwig, "On What Should We Focus Our Early Interventions to Maximize Benefit-Cost Ratios?" (paper presentation, Robin Hood Early Childhood Institute planning meeting, New York City, January 2011).

Other MDRC Publications on Making Pre-K Count and High 5s

Launching Kindergarten Math Clubs
The Implementation of High 5s in New York City
2018. Robin Jacob, Anna Erickson, Shira K. Mattera

Counting on Early Math Skills
Preliminary Kindergarten Impacts of the Making Pre-K Count and High 5s Programs
2017. Shira Mattera, Pamela Morris

Making Pre-K Count
Improving Math Instruction in New York City
2016. Pamela A. Morris, Shira K. Mattera, Michelle F. Maier

NOTE: All the publications listed above are available for free download at www.mdrc.org.

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