Math Coaching with Preschool Teachers in Los Angeles: Evidence for Teacher Knowledge Gains and Improvement in Children's Math Skills

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Table of Contents

Introduction

Background

Nationally, there is a growing emphasis on academics in preschool classrooms as researchers have underscored the importance of aligning preschool with elementary school curricula (Stipek et al., 2017). In California, academic domains such as literacy, language, math, and science are included in the state-proposed California Learning Foundations that detail learning expectations for children prior to kindergarten entry (California Department of Education, 2008). However, there is no standard for California public preschools to adopt evidenced-based curricula that target these areas of school readiness skills. As a result, despite the requirement of California public preschools to assess children on school readiness skills, including academics (Desired Results Developmental Profile (DRDP)), emerging evidence has demonstrated that only 30% of California preschoolers meet kindergarten readiness goals by the time they enter kindergarten (Kriener-Althen, et al., 2020).

With no standard for curricula, instructional coaching is one avenue to better support preschool programs prepare children for kindergarten. In Los Angeles specifically, there is evidence to suggest that preschool teachers are particularly lacking in support and coaching for their *math instruction* (Barrett, 2017), which is reflected in children's learning outcomes. For example, in contrast to literacy and language skills, children who attended preschool in the Los Angeles Universal Preschool network did not differ from their non-attending peers in math skills at kindergarten entry (Kyger & Barnhart, 2017). This is unsurprising considering math learning consists of perhaps the most nuanced developmental learning sequence. Unlike literacy skills—which stem from knowledge in phonological awareness—math involves multiple topics that each require their own foundational knowledge base. For instance, how children develop patterning skills is independent from how they learn to identify shapes and count objects.

To date, most domain-specific coaching efforts have focused on literacy (Hsieh, et al., 2009; Powell, et al., 2010; Wasik & Hindman, 2011; Wasik, et al., 2006;) and fewer have focused on math (Clements & Sarama, 2007), which may be due in part because of the emphasis educators put on language, literacy, and social-emotional learning, rather than math (Weiland, 2016). Yet, it is empirically clear that math learning matters for children's developing school readiness skills, even for domains outside of math, like reading (Purpura et al., 2017). This signifies a need in the literature to create and evaluate more coaching efforts targeting math teaching, especially in California public preschools resources for math teaching are scant.

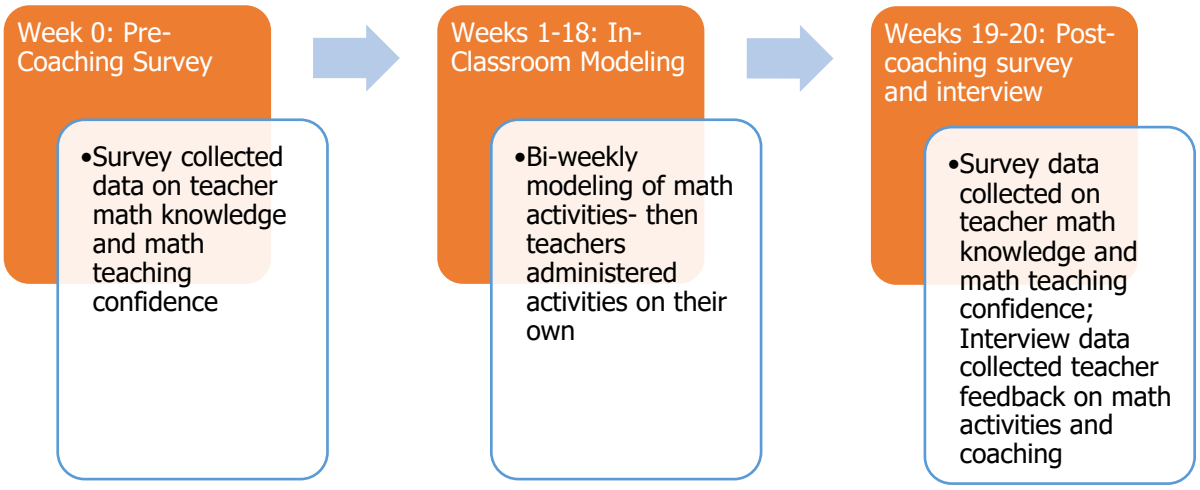
Providing detailed training and coaching on children's math development and targeted activities for specific skills gives teachers the knowledge needed to improve upon children's math development. As such, the current study developed, piloted, and observed a math training, provided math materials, and scripted activities with a sample of teachers and students in Los Angeles preschools.

Study Details

The goal for Year 1 (2019-20) of this study was to examine the coaching of math activities and how it was associated with teachers' knowledge and confidence in math. Coaches modeled math activities for the teachers over the course of 18 weeks, and pre- and post-coaching surveys were administered to measure whether the coaching was related to teachers' knowledge and confidence in math. The goal for Year 2 (2021) was to focus on child math learning outcomes across seven distinct math skills. Children were given the new math intervention while teachers were given the training, and pre- and post-intervention math tests were given to the children to measure whether they gained new math skills.

More specifically, in Year 1 six Head Start centers in Los Angeles (12 lead teachers) participated in the coaching of math activities that covered an array of math topics such as shape knowledge, patterning, early addition, measurement, counting, and numeral identification skills. The coaching covered 1) the development of each math topic 2) scripted activities that provided scaffolding from one developmental level to the next 3) appropriate material usage to teach the math topics, and 4) in-classroom modeling of the activities. For an overview of Year 1, see Figure 1.

Figure 1. Overview of Study Design: Year 1 - 2019/2020



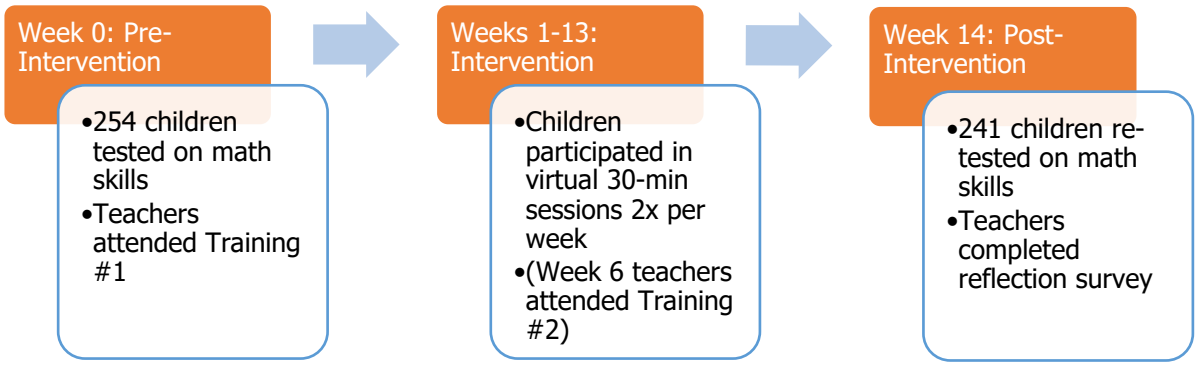
For data collected in Year 1, we gathered interviews and questionnaires to track teacher math knowledge and further identify strengths and weaknesses of the approach. Results from Year 1 helped to refine the coaching and activities for the following year of implementation (Year 2). For an overview of the subset of activities used in Year 2, see Table 1.

Table 1. Description of Math Activities (Six Key Activities for Year 2)

	Target skill	Description	Key levels
Number Freeze	Verbal counting	Children crouch upwards counting 1-10; Freeze at a specific number; Then count-on from that number	1.) Count 1-10 without skipping numbers 2.) Counting 1-20 without skipping numbers
Number Search	Numeral identification	Children search for a specific number in an array of number cards ("Find all the green 3's")	1.) Identify numerals 1-5 2.) Identify numerals 1-10
Shape Search & Sort	Shape identification	Children search for a specific shape in an array of shape cards, and sort based on a specific rule ("Find all the green triangles") ("Put the 3-sided shapes in one pile, and the 4-sided shapes in another")	1.) Identify circle, triangle, square/rectangle 2.) Identify triangles of different orientations; Can identify shape based on number of sides (can count the sides)
ABC's of Patterning	Copy, extend, create patterns	Children use colored "A" "B" pattern templates to first copy patterns, then rely on black/white templates, then rely on just a blank template with "A's" and "B's"	1.) Copy/Extend an AB pattern 2.) Copy/Extend an ABB pattern
Measuring Worms	Measurement vocabulary, Linear measurement units	Children practice comparing objects e.g., taller, shorter, smaller, wider etc. Then practice comparing length of objects using a repeating unit	1.) Developing measurement vocabulary 2.) Measuring objects
Shape Building	Shape attributes	Children use magnet sides (long and short) and connecting balls to build shapes	1.) Build a triangle from scratch 2.) Distinguish between rectangle and square

In Year 2 (2021), the coaching study included 10 more Head Start centers, with the explicit aim of providing virtual math support for children during the COVID-19 pandemic who were entering kindergarten in the fall of 2021. A total of 43 teachers, including both lead and teaching assistants, and 254 five-year-old preschoolers participated in this virtual math program that lasted a total of 13 weeks (March – June). This virtual program was an additional session on top of children's existing virtual "school"—which for many children only occurred as a biweekly interaction with their teacher. Before the program began, all teachers participated in a 2-hour training covering the development of children's math skills and the scripts and modeling of the first three math activities. Child360 researchers also tested children's math skills using the Research Based Early Mathematics Assessment (REMA; Clements, et al., 2008). Each teacher formed small groups (of 2-6) with children consented to be in the study. These groups met 2-3x per week for 30-minute virtual sessions. Each child received their own home math materials toolbox that included materials needed for the activities such as bear counters, magnetic sides/balls for shape building, shape cards, numeral cards, math link cubes, and patterning templates. In the first six weeks of the program, activities focused on children's counting skills, numeral identification, shape recognition, and patterning skills. Teachers met weekly with the Child 360 math specialist for any questions they had in administering the activities. After the first six weeks, teachers then participated in a second 2-hour training to provide coaching on the remaining activities that covered shape construction and attributes, early addition and subtraction, and measurement. At the end of the 13 weeks, Child360 researchers asked teachers to complete a reflection survey and tested children's math skills. For an overview of the study design, see Figure 2.

Figure 2. Overview of Study Design: Year 2 - 2021



Research Questions

1) Year 1: How did teachers respond to the math activities and training? Did teachers improve in their understanding of children's math development and teaching?

2) Year 2: Did children improve in their math skills after participating in the extracurricular math activities?

Findings: Teacher response to math coaching and evidence of knowledge gains

Year 1: Overall, teachers had a positive response to the format of the math coaching and the content of the scripted activities. Using the Framework Approach to analyzing qualitative data (Pope, et al., 2000), results from the teacher interview conducted in the first year of the study revealed several themes highlighting the strengths and weaknesses of the math coaching. Teachers enjoyed the in-classroom modeling, variety of materials, and the activity scripts. However, the teachers would have liked more formal training on children's math development as it related to the CLASS (Classroom Assessment Scoring System) and the DRDP (Desired Results Development Profile), and teachers would have also liked more support on how to help children of the lowest math skill level. At the end of the coaching, teachers also rated each activity on a scale of 1 to 5 across factors such as child engagement (e.g., 1= all children not engaged, 5=all children engaged), ease of implementation (e.g., 1= very difficult to implement, 5= very easy to implement) confidence in understanding the developmental sequence (e.g., 1= not confident in what skill comes first and then next, 5=very confident…), and likelihood of continuing to use the activity

(e.g., 1= not likely at all, 5= very likely). Six out of 12 activities received a rating of four or above on all dimensions. As such, Year 2 of the study then used these six highly rated activities (refer back to Table 1). These findings from Year 1 also implied that the activity scripts and the developmental breakdown of each skill should remain the same, although given teacher feedback, Year 2 activities included more introductory levels for geometry and measurement . Additionally, given the response from teachers, Child360 staff created an official training, which provided explicit integration of math activities with the DRDP and CLASS tools. An overview of the teacher feedback from Year 1 is presented in Table 2.

Table 2. Qualitative Themes of Math Coaching Strengths & Weaknesses

	Strengths (> 50% teachers mentioned)	**Weaknesses (> 50% teachers mentioned)**
Content	Variety of math materials helpful; Children very engaged in most activities; Breaking down math activity into specific skills is helpful	More materials for small-group; Not enough "introductory-level" activities—especially for geometry and measurement
Coaching	Teachers liked the in-classroom modeling approach; Teachers liked the weekly check-ins; Teachers liked how coaching accompanied an activity script	More coaching for how to support children of the lowest skill level; Coaching should integrate more with existing classroom tools like the DRDP and the CLASS; An official group training would be helpful

Year 1: Teachers reported an increase in their knowledge of math vocabulary and children's math readiness. Another goal of Year 1 was to determine whether the coaching increased teacher knowledge of math teaching. Child360 researchers assessed this by using interview data to identify themes in teacher responses of what they learned. In the final interview, two themes emerged as evidence for teacher knowledge gains. First, there was an overall increase in teacher knowledge of math vocabulary. For example, more than 50% of teachers noted how the coaching taught them more "math terms" such as the difference between "cardinality" and "one-to-one correspondence"; and having terms for these skills helped teachers better conceptually distinguish the skills. Second, teachers reported an overall increase in their knowledge of child math skill readiness. For example, more than 50% of teachers noted that they did not realize that children were "ready" to learn certain math skills such as early addition and subtraction, advanced patterning, and composing a variety of shapes. An overview of teacher-reported knowledge gains is in Table 3.

Table 3. Interview Quotes – Teacher-Reported Knowledge Gains

Theme 1: Learned more math vocabulary
• "Learned more words for math like cardinality, one-to-one correspondence, trapezoid, rhombus"
• "Asking 'how many?' is a key question and that this is different from assessing a child on if they can just count"
• "Didn't know what a rhombus was"
• "That long and short are the correct words to use for teaching measurement I always use bigger and smaller, but I see that [big/small] is more for the teaching of sizes"
Theme 2: Learned more about children's math skill readiness
• "Never knew that children could create shapes. Just thought we needed to teach what the shapes are called."
• "Didn't know children could continue a pattern I always just teach them to repeat them, and I liked teaching with the templates"
• "I was not sure that children were ready for addition and subtraction in preschool, but many kids caught on quickly to the house game"
• "It's interesting that just because a child can count doesn't mean they understand what number means. I found that fascinating"
• "I did not realize that working with the small numbers, like with the addition and subtraction keeping the total under 5, is a good idea before moving on to the bigger numbers".

Year 1: Teachers demonstrated an improvement in their knowledge of the development of children's patterning and geometry skills. Teachers were assessed on knowledge gains via a teacher questionnaire that asked teachers to describe which skill came first within a specific math domain (in the context of the activity). Post-coaching, this questionnaire revealed that teachers improved the most in their understanding of two key math skills. First, teachers improved in their knowledge of how children learn and develop patterning skills. For example, by the end of the intervention teachers were able to articulate how children first copy "AB" patterns, then learn to extend these patterns, identify and extend ABB/AAB patterns, and then begin to switch between the usage of different "AB" units and successfully create their own patterns. Second, teachers improved in their knowledge of children's geometry development. For example, teachers were able to articulate how children first learn to identify circles, then triangles and squares/rectangles, then how to count the sides, then they transition to building their own shapes, recognizing learned shapes (like a triangle) in different orientations, and identifying the difference between a rectangle and a square. Some improvements appeared in the other math domains, but these improvements were not statistically significant. Despite the promising qualitative data Child360 researchers collected that pointed to an increase in teachers' knowledge of number sense development (like knowing the difference between cardinality and one-to-one correspondence), teachers improved the least with their understanding of this domain. This is unsurprising, however, considering number sense includes more subskills to keep track of (e.g., numeral identification, recite counting, cardinality etc.) compared to patterning and geometry (Clements & Sarama, 2004). Due to these results, Year 2 math coaching focused more on the distinction between the number sense subskills but preserved the existing coaching structure for patterning and geometry development.

Findings: Evidence for gains in children's math skills in Year 2

At the beginning of the math coaching program, 38% of children could not identify any numbers, 40% of children could not copy a simple pattern, and for 29% of children, the only shape they could identify was a circle. Results from the math pre-test revealed that 5-year-olds in their last year of preschool were behind in several key math skills for kindergarten readiness. Table 4 illustrates the percentage of students who met the kindergarten readiness goal in March 2021, just months before graduating preschool, and again after the math coaching ended in June 2021. These baseline results are unsurprising because math learning during the pandemic took a backseat for many teachers. Especially when it came to recognizing numerals and shapes—that require substantial repetition—unless the parents worked with their child outside of school, the infrequent "school" sessions were unlikely to provide the level of repetitive exposure needed to learn shapes and numerals.

Table 4. Percentage of Children that were Kindergarten Ready in March 2021 vs. June 2021

Kindergarten Readiness Skill	March 2021	June 2021
Count from 1-20 without skipping numbers	17%	45%
Identify numerals 1-10	25%	58%
Understands "how many"; keeps track when counting objects up to 10	40%	73%
Can combine small quantities (by counting all or counting on); Demonstrate understanding of adding 1 and 2	24%	51%
Can identify shapes based on the number of sides (triangles in different orientations); Can distinguish between a square and rectangle	13%	33%
Can identify the repeating unit of a simple pattern; Can extend ABB patterns	7%	38%
Demonstrates an understanding of measurement vocabulary; Can order and compare objects depending on the measurement unit	17%	22%

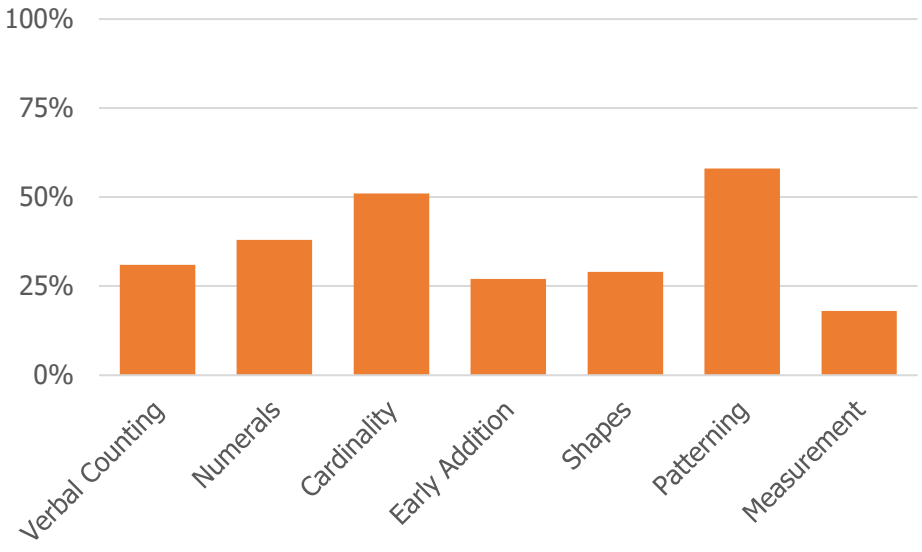
Note. 13 children were unable to be tested post intervention

After 13 weeks in the program, children improved across the seven key math skills, but children improved the most in their patterning skills and understanding of quantity (e.g., cardinality). At the end of the intervention, several children made improvements in at least one developmental level of a given math skill. For example, consider one child who started the program unable to count smoothly from 1-10 (level 0), but by the end of the program was able to count from 1-10 without skipping numbers (level 1). This child would still not be considered "kindergarten ready" because they could not yet count smoothly from

1-20 without mistakes (level 3), but this child was still considered to have improved at least one level within this domain. Figure 3 illustrates the percentage of students who improved in at least one level of each math skill domain. As evidenced by the graph, 17% of children improved in their measuring skills, 27% improved in their early addition skills, 30% improved in their recognition of shapes, 31% improved in their verbal counting 38% improved in their identification of numerals, 51% improved in their understanding of quantity, and 58% of children improved in their patterning skills.

Since teachers improved the most in their understanding of patterning development, it is not surprising that children also improved the most in this skill. Although teachers improved less in their understanding of children's development of quantity (e.g., cardinality), this skill is one that is most likely to improve rapidly with young children at this age. For example, pre-coaching, many children were on the cusp of developing an understanding of quantity, as they could count objects, but were not able to answer: "how many?" (e.g., they would just re-count the objects). As part of the training, many teachers were encouraged to ask: "how many?", after each time a child counted objects, and gesture to all the objects to answer for them if the child could not answer. This repetition in itself (despite a teacher being unable to fully articulate the development of this skill) may have helped children improve upon their understanding of quantity, and why we see such substantial child gains in this domain.

Figure 3. Percentage of students who gained at least one level within each math skill



Conclusions and Recommendations for Future Math Coaching

Preschool teachers appreciate when activity suggestions are scripted and explicitly aligned with existing teacher tools. A big barrier for teachers is that they do not have enough "ideas" for math activities—especially when it comes to the variety of child skill levels in the classroom and the variety of math skills needing to be taught. In Year 1 of this study, it became clear that teachers were overwhelmed with administering the DRDP assessment and increasing their classroom quality scores on the CLASS. So, in Year 2, Child360 researchers more explicitly aligned the activities with the DRDP and CLASS indicators. For example, each activity suggestion highlighted the specific DRDP COG (Cognition Category), as well as the Instructional Support indicator (e.g., Analysis & Reasoning). Until the standards for public preschools in California include evidenced-based curricula, integrating existing coaching tools with academic domains may be a promising alternative.

Preschool math coaching is effective when each math skill domain is isolated, and coaches model the step-by-step development. Teachers reported that the isolation of each math skill made it easier to see how each skill is developmentally distinct from another, and modeling how a child moves from one level to the next makes it easier for teachers to scaffold. Below are some of the major preschool math teaching themes that Child360 researchers uncovered during this study.

Teacher Lessons Learned

Counting is not the same as an understanding of quantity.

A child counting smoothly from 1-10 does not necessarily mean they understand what "10" means or can count out 10 objects.

Children need repeated exposure to numerals, but in small doses.

When children are first learning numerals it is natural to introduce numerals 1-10, or even 1-30 (especially when teaching the calendar) but starting with repeated exposure of 1-5 before moving on to larger numerals is a more efficient learning process for children.

Children need to develop an understanding of the repeating unit in patterns.

When children are learning patterns, it is important to highlight the unit that is repeating and introducing the "AB" terminology to them. A common mistake in math teaching is just having children copy patterns without having them isolate the unit. Once they can do that, they can switch between different types of materials—and what is "A" and "B"—more easily when patterning.

Children need to build a foundation of shape attribute knowledge before introducing too many shapes.

When children are learning shapes, it is important to focus on what makes a triangle a triangle (e.g., 3 sides), and what makes a square a square (e.g., 4 *equal* sides). A common mistake in math teaching is focusing on quantity of shapes—like introducing a hexagon and rhombus—before a child can recognize different orientations of triangles or understand what makes a square and rectangle different.

Children need more practice with measurement vocabulary before pulling out the measuring tape.

In multi-lingual communities like Los Angeles in which language learning is especially important, emphasizing and teaching the correct measurement vocabulary like the difference between big/small, tall/short, wide/narrow, heavy/light is important before introducing *how* to measure. Gaining the vocabulary to describe relative quantity in the language(s) of instruction is a necessary precursor to understanding more complex mathematical operations.

Disclaimer: The COVID-19 Context

It is important to highlight how the generalizability of this study—especially the findings from Year 2—are limited to the context of the COVID-19 pandemic. It is possible that because children were so behind in their math skills, any additional assistance was helpful for their math development (e.g., there was nothing special about this specific math coaching or activities; children had a lot of room for "gain"). Likewise, this program may have been even more successful if administered in person and not in a virtual setting. However, the virtual setting was more successful than planned as many teachers noted that the fact that children had their own materials in the home made all the difference; children were able to be more hands on, as opposed to being more passive learners over the virtual platform. Relatedly, and most importantly, it is crucial to highlight that this work is not causal. We originally wanted to randomize some children to a control condition where they received no math support, to precisely evaluate the effect of the program. But ultimately, Child360 researchers decided all children should receive this extra math support considering the impact COVID-19 has had on these children, as well as the request from parents to receive more instructional support for children. With children spending a large amount of time at home, Child360 researchers also found it would be difficult to ensure a properly controlled comparison group.

Ultimately, despite the lack of causality in this study, our qualitative data do suggest that math coaching increased teachers' math teaching knowledge, and that this extra support helped prepare hundreds of Los Angeles preschoolers for kindergarten.

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