Learning with PBS KIDS

A Study of Family Engagement and Early Mathematics Achievement

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Highlights of the Findings

In 2014, WestEd conducted a study of family engagement and early mathematics learning as part of the *Ready To Learn* (RTL) Initiative with the Corporation for Public Broadcasting (CPB) and the Public Broadcasting Service (PBS). The study was designed to test the effectiveness of a school-based family engagement model in increasing preschoolers' knowledge and skills in mathematics, and in increasing parents' awareness of and ability to support their children's mathematics learning in the home environment. Additionally, the study focused on the feasibility of having teachers from participating schools facilitate parent meetings related to the intervention. The study also examined the relationship of socioeconomic status to learning outcomes and explored how key aspects of the model affect family engagement and learning.

Students' Knowledge and Skills in Mathematics Improved

- Students' overall knowledge of mathematics improved, as measured by the Test of Early Mathematics Ability (v.3), with the intervention group's scores on the post-test being higher on average than those of the comparison group (point estimate of 2.93; minimum detectable effect size [MDES] = 0.22, a finding that was statistically significant at the 0.05 level).
- Intervention group children also grew in their understanding of basic and advanced shapes, as measured by a researcher-developed assessment, with significant improvements in the number of children correctly recognizing circle, triangle, trapezoid, and pentagon (findings that were statistically significant at the 0.04 level or higher).
- The analyses indicate that intervention group children at all income levels increased in their mathematics ability.

Parents' Awareness and Support of their Children's Mathematics Learning Increased

- Analyses of data on parent awareness suggest that intervention parents' awareness of their children's mathematics learning grew significantly compared to parents in the comparison group (a finding that was statistically significant at the 0.04 level).
- Analyses of data on parent support suggest that intervention parents' support of their children's mathematics learning grew significantly compared to parents in the comparison group (a finding that was statistically significant at the 0.01 level).

- Analysis of focus group data shows that intervention parents refreshed their own knowledge of mathematics, integrated mathematics learning throughout the day, became better prepared to support their children's learning, set aside time each day to focus on learning, began to target learning interactions with their children on specific areas of math, and worked collaboratively with their children to provide context-sensitive support.

Teachers Were Successful at and Enjoyed Facilitating the Parent Meetings

- Observation notes and teacher interview data suggest that preschool teachers at the intervention sites were successful facilitators of parent meetings. Not only did teachers deliver intervention activities with fidelity, they provided parents with a deeper connection to the preschool.

Overall, the study's findings suggest that the intervention model, using a family engagement learning experience that includes PBS KIDS transmedia content, is effective in supporting families and contributing to growth in preschool children's mathematics competencies and can be scaled to reach a broader preschool audience. CPB and PBS plan to make the materials used in the study available in 2016 to public media stations, educators, and other interested organizations. Titled the *WestEd/PBS KIDS Family Engagement Program*, the materials will be available on the PBS website.

Executive Summary

There is an acute need in the United States to boost mathematics competencies in young children, particularly those from economically disadvantaged families, as early mathematics ability is a strong predictor of later academic achievement. Research has shown that family engagement can be effective in improving preschoolers' mathematics learning. During the summer of 2014, WestEd conducted a study of family engagement and early mathematics learning as part of the *Ready To Learn* (RTL) initiative with the Corporation for Public Broadcasting (CPB) and the Public Broadcasting Service (PBS). The study was designed to test the effectiveness of a school-based family engagement model in increasing preschoolers' knowledge and skills in mathematics, and in increasing parents' awareness of and ability to support their children's mathematics learning in the home environment. Additionally, the study focused on the feasibility of having teachers from participating schools facilitate parent meetings related to the intervention. The study also examined the relationship of socioeconomic status to learning outcomes and explored how key aspects of the model affect family engagement and learning.

Funded by the U.S. Department of Education, the CPB-PBS RTL Initiative has a goal of promoting early learning and school readiness among children ages 2 through 8, with a particular interest in reaching children from low-income families. The Initiative supports the development and delivery of high-quality, age-appropriate, educational content designed to increase the early literacy and mathematics competencies of young children.

The family engagement model was developed over the past three years, and earlier versions were tested in two previous studies (McCarthy, Li, & Tiu, 2012; McCarthy, Li, Atienza, Sexton, & Tiu, 2013). The latest study builds on these past two studies by developing a scalable model that can be implemented in different preschool locations and by assessing the feasibility of having local preschool staff facilitate its weekly parent meetings.

The Intervention

The family engagement model that is the focus of this report used the capabilities of PBS KIDS transmedia suites along with best practices in family engagement to increase parents' capacity to support their children's early mathematics learning. The intervention focused on two overarching mathematics concepts included in the transmedia suites: numbers and operations in base ten, and shapes. The intervention lasted nine weeks and prompted parents and their children to work together on PBS KIDS transmedia activities

for 30 minutes per day for four days per week, and encouraged parents to attend weekly parent meetings at their child's preschool.

The intervention model included four days of activities for children at home. Parents of children in the intervention group received a weekly program of PBS KIDS transmedia activities to use with their children, as well as parent support materials consisting of hands-on home activities printed from PBS KIDS Lab and a binder including summaries of the specific assignments for the days of the week. During the week, intervention families accessed the intervention materials via Google Chromebooks they were provided with to take home for the duration of the study. A 3G data plan was provided for each Chromebook so that participants could access the Internet. The Chromebook browser and settings were configured such that participants had access only to the specific PBS websites included in the intervention.

During each week of the study, parents or other family members (such as grandparents, uncles, aunts, and older siblings) receiving the intervention met at their child's preschool for one hour at the end of the school day. Parents were encouraged to attend a total of nine parent meetings, one for each week of the intervention. During each parent meeting, parents were encouraged to describe the activities they undertook with their children the previous week, including whether they felt their children learned from those activities and what challenges they encountered.

To explore the possibility of scaling the intervention to reach a larger audience, staff from the intervention preschools participated in six hours of facilitator training sessions to learn how to conduct the weekly parent meetings. The staff from the intervention preschools independently facilitated the nine parent meetings at their preschools. Parent meetings were conducted in both English and Spanish.

Study Design and Components

The study applied a combination of quasi-experimental design and qualitative observations to address several research questions. The study addressed two primary questions about the effectiveness the family engagement model:

1. Does the parent engagement model intervention increase children's knowledge and skills in mathematics?

2. Do parents' awareness and support of their children's mathematics learning at home increase after taking part in the intervention?

In addition, the study explored the effectiveness of having preschool staff facilitate the parent meetings that are part of the intervention, as having teachers in this role could increase the possibility of scaling the intervention to reach a broader audience:

3. Is it feasible for teachers from participating schools to successfully facilitate parent meetings related to the intervention?

Another goal of the study was to explore the relationship of socioeconomic status and learning outcomes:

4. How did any changes in students' knowledge and skills in mathematics relate to the students' socioeconomic status?

Parents and children from nine preschools were recruited to participate in the study. WestEd recruited families from preschools serving economically and ethnically diverse communities in San Mateo County, California. Participants from three preschools received the intervention, as described above, and participants from the other six preschools served as members of a comparison group.[1] Comparison group families used business-as-usual mathematics games, videos, and supporting materials. These materials were not provided by WestEd researchers, but were educational materials that parents would normally have used with their children. Comparison group parents met twice throughout the study, once during the first week of the study and again during the final week of the study. At the first meeting, parents were given a list of suggested mathematics topics to engage in with their children. These topics aligned with the skills that intervention group children practiced in the PBS KIDS transmedia suites. At the last meeting, parents were encouraged to describe what activities they had done with their children and were given several educational books to use with their children as a gift for participating in the study.

Two tests were given to students in both the intervention and comparison groups before the intervention and again after the intervention was completed: the Test of Early Mathematics Ability, third edition (TEMA-3), a standardized, nationally normed achievement test of children's informal and formal mathematics knowledge[2] (Ginsburg & Baroody, 2003); and a researcher-developed assessment of mathematics skills related to the concept of shapes using eight items from or adapted from the Child Math Assessment (Klein, Starkey, Clements, Sarama, & Iyer, 2002). The eight items on this assessment showed good reliability on the pre-test (alpha = .84) and on the post-test (alpha = .82). TEMA-3 and the researcher-developed assessment were used to test the baseline equivalence between the intervention and comparison groups and served as covariates in the outcome analyses.

A parent survey, adapted from Home Learning Environment (HLE) survey (Starkey et al., 1999), and parent focus groups were used to gather more baseline information, such as the demographics of participants, and to gather outcome data, including parents' awareness of and support for their children's mathematics learning and parents' perspectives on the intervention. All families took the parent survey before and after the intervention, and 95 percent of families in the intervention group took part in parent focus groups.

Study Results

Children's Knowledge and Skills in Mathematics Improved

The quantitative assessment data (from TEMA-3) indicate that the intervention was positively associated with gains in children's knowledge and skills in mathematics. Adjusted mean differences on TEMA-3 scores show that the intervention group's scores on the post-test were higher on average than those of the comparison group (point estimate of 2.93; minimum detectable effect size [MDES] = 0.22), a difference that was statistically significant (at the 0.05 level) after accounting for differences in baseline test results and participant ethnicity. On the researcher-developed assessment focusing on the concept of shapes, the intervention group also improved more than the comparison

1 This study was approved by an independent Institutional Review Board (IRB).

2 The test is designed for use with children ages 3 through 8. It measures four categories of informal mathematics: Numbering, Number Comparisons, Calculation, and Concepts. It also measures four categories of formal mathematics: Numeral Literacy, Number Facts, Calculation, and Base 10 Concepts.

group. Prior to the intervention, the intervention group had significantly lower scores than the comparison group on this assessment, but after the intervention, the two groups (intervention and comparison) had similar mathematics scores related to shapes. Though only two weeks of the intervention focused on shapes, intervention group children grew in their understanding of basic and advanced shapes, including significant improvements in the number of children correctly recognizing circle, triangle, trapezoid, and pentagon.

All Socioeconomic Levels Improved in Mathematics

The analyses indicate that intervention group children at all income levels increased in their mathematics ability. A descriptive analysis of the intervention group data indicates that TEMA-3 scores increased on average more than six points for children identified as low-income and for those not identified as low-income.[3]

Parents' Awareness of Their Children's Mathematics Learning Increased

Analysis of quantitative data suggests that the intervention parents grew significantly in their awareness of their children's mathematics learning. To detect whether the family engagement model increases parents' awareness of their children's mathematics learning at home, researchers analyzed the composite sum score from the HLE survey items related to awareness of mathematics. The survey items ask parents about their knowledge of preschool children's mathematics abilities and skills.

Parents' Support of Their Children's Mathematics Learning Increased

Analyses of the quantitative data also suggest that intervention parents increased their use of activities and strategies to support their children's mathematics learning. Researchers analyzed the composite sum score from the HLE survey items related to parents' support for learning at home. The score includes 28 survey items about the availability and use of books, store-bought games, educational technology, and other educational resources in the home.

Themes from Qualitative Data Analysis

Researchers analyzed the qualitative data to generate themes, using a combination of grounded theory (Strauss & Corbin, 1998) and established methods for coding qualitative data (Miles & Huberman, 1994) to identify and categorize the participants' responses. Findings from qualitative coding help explain changes in parents' and children's knowledge and behavior.

Parents Reported Increases in Children's Knowledge and Skills in Mathematics

Analysis of qualitative data from the parent focus groups indicates that, over the course of the intervention, parents noticed growth in their children's understanding of the intervention's targeted mathematics concepts. Nearly all parents taking part in the 11 focus groups mentioned that they observed their children learning new mathematics content. The following quote is typical of the majority of intervention-group parents who participated in focus groups.

3 Possible experimental scores range from 0 to 210.

> *He learned a lot. He learned to add small figures, less than ten. Before, he didn't know any adding. He now knows the numbers up to 12 and he also identifies shapes.*

Parents' Awareness of their Children's Mathematics Learning Increased

Analysis of qualitative data from the parent focus groups indicate that, over the course of the intervention, parents noticed growth in their children's understanding of the intervention's targeted mathematics concepts. Nearly all parents taking part in the 11 focus groups mentioned that they observed their children learning new mathematics content. The following quote is typical of the majority of intervention-group parents who participated in focus groups.

> *He learned almost all the shapes except he still gets confused with hexagon, pentagon and octagon. He only gets confused with those three, but he knows how to count the sides, he knows how many sides it has.*

> *This [intervention] makes you think that even though they're so young, their minds are growing and they're really smart and they catch onto everything. [They are] building on everything.*

Parents Refreshed Their Own Knowledge of Mathematics

Many parents mentioned that the intervention had refreshed their understanding of mathematics, helping them learn or re-learn mathematics concepts.

> *I didn't have a program like this when [my other kids] were younger, and I didn't do math at that age. It [the intervention] helped me a lot with math.*

Parents Integrated Mathematics Learning Throughout the Day

Qualitative data also indicate changes in parents' level of interaction with their children around math.

> *We started counting everyday objects. When we go out, or we go to the grocery store, I say, 'Can you find me a thing of bananas that has five bananas on it, one for each of us?' She'll count the bananas and find the one for each of us. Stuff like that.*

Parents Learned New Skills, Becoming Better Prepared to Support Their Children's Learning

The majority of intervention parents in the focus groups mentioned that they learned new skills and strategies from the intervention that allowed them to enrich their learning interactions with their children.

> *It [the intervention] was good because it helped me to consciously think more about asking her questions, about counting and colors and shapes and stuff like that. Which I did before, but I didn't consciously do it as often as I would do now. Like, everyday objects that pass us by throughout the day.*

Another group of parents said participating in the intervention opened their eyes to the importance of supporting their children's mathematics learning.

> *It [the intervention] just made me think. It kind of opened a door for me, that I could teach them this and I could teach them that. Even though they're little, they're really smart and they catch on fast to everything, and you can take that further.*

Parents Set Aside Time Each Day to Focus on Learning

About a quarter of the parents in focus groups said that the intervention motivated them to spend time with their children and focus on mathematics learning.

> *Now we put aside more time to our children. Before we didn't do it because we didn't have enough time and now we feel more interested in spending at least half an hour or more with them.*

Parents Began to Target Learning Interactions

A majority of parents said they grew in their ability to focus learning interactions with their children on the specific areas of mathematics.

> *She likes it when I test her. I'll be like, 'You know, the counting by fives? Remember the fives?' We'll go back to the [game] and see what score she gets. I'll be like, 'Okay, I'm going to do a test. Go!'*

Parents Worked Collaboratively with Children to Provide Context-Sensitive Support

Analyses suggest that many parents learned a new way to actively participate in learning activities with their children and provide support to their children when necessary.

> *For me, with my daughter, it was fun. The best thing for us was about doing the activities together, and to show her how to learn. I learned how to ask her more questions. It was fun because we found a way to learn together.*

Parents Gravitated to a Learning Environment that Encourages Playfulness and Positive Affect

Another concept that emerged during analysis is that of playfulness and positive affect. Many parents reported they increased their use of fun, games, and playfulness to more deeply engage their children during learning interactions.

> *I would act like I didn't know, and he would do it fine, and he would laugh at me because he'd say, 'I beat you, you didn't know!'*

Teachers Were Successful at and Enjoyed Facilitating the Parent Meetings

Data regarding fidelity and teacher interview data suggest that preschool teachers at the intervention sites were successful facilitators of parent meetings. Not only did teachers deliver intervention activities with fidelity, they provided parents with a deeper connection to the preschool.

Nearly all teachers reported they enjoyed the experience of teaching parents. In particular, they enjoyed seeing parents grow in their awareness of and ability to support their children's mathematics learning. One teacher commented:

> *If we have done anything, I think the most exciting is to see more awareness [in the parents] of math all around. If that is something we did, I think it was to at least open their eyes to see that there was math everywhere and that they can use it. You know, by being in the car and playing a simple game of counting cars. Just opening their eyes to that.*

Families Responded Positively to Elements of the Intervention

Analysis of the focus group transcripts indicates that intervention parents particularly appreciated three elements of the intervention: its daily routine, its high-quality content, and the transmedia aspects of the intervention.

Conclusion

Overall, the study's findings suggest that the intervention model — using a family engagement learning experience that includes PBS KIDS transmedia content — is effective in supporting families, contributes to growth in preschool children's mathematics competencies, and can be scaled to reach a broader preschool audience.

Families taking part in the intervention appreciated the community-based environment with daily activities and playful, easy-to-access mathematics content. The PBS KIDS transmedia content appears to have contributed to the success of the intervention. Parents and children enjoyed the engaging games, videos, and hands-on activities, and parents mentioned that the content helped their children learn mathematics. They appreciated that their children could learn and practice concepts in various modalities, whether it involved playing a counting game using cards with a family member, or playing a digital game that supports children as they learn to count to higher levels. Parents also appreciated the quality of the PBS KIDS transmedia content, frequently mentioning that they could see that the content was well designed to support learning in an engaging format.

The results of the study also indicate that the current model is promising for boosting young children's mathematics knowledge and skills. This site-based transmedia family engagement model helps parents provide mathematics support to their young children. Additionally, training teachers at preschool sites to deliver the curriculum appears to be feasible. These results suggest that broadly scaling up the intervention to additional preschool settings could prove effectual and cost-effective.

The intervention was developed with funding from the U.S. Department of Education as part of the CPB and PBS *Ready To Learn* initiative, which supports children and family learning through the development and dissemination of multiplatform math content for preschool children, especially those from low-income families. CPB and PBS plan to make the materials used in the study available in 2016 to public media stations, educators, and other interested organizations. Titled the *WestEd/PBS KIDS Family Engagement Program*, the materials will be available on the PBS website.

Introduction

There is an acute need in the United States to boost mathematics competencies in young children, particularly those from economically disadvantaged families, as early mathematics ability is a strong predictor of later academic achievement. Research has shown that family engagement can be effective in improving preschoolers' mathematics learning. Accordingly, during the summer of 2014, WestEd conducted a study of family engagement and early mathematics learning as part of the *Ready To Learn* (RTL) Initiative with the Corporation for Public Broadcasting (CPB) and the Public Broadcasting Service (PBS).

Among the study's main findings are that mathematics knowledge increased significantly for children from both low-income and higher-income families who received the intervention, and parents' awareness of their children's math learning increased significantly, as did their use of strategies to support their children's learning. The study also found that providing professional development for on-site teachers to facilitate the intervention's weekly parent meetings may be an effective avenue for scaling up the parent engagement model.

Funded by the U.S. Department of Education, the CPB-PBS RTL Initiative has a goal of promoting early learning and school readiness among children ages 2 through 8, with a particular interest in reaching children from low-income families. The Initiative supports the development and delivery of high-quality, age-appropriate, educational content designed to increase the early literacy and mathematics competencies of young children.

The study described in this report tested an intervention involving a family engagement model designed to promote mathematics learning in preschool children. The intervention model includes a school-based curriculum whereby families attend weekly parent support meetings for nine weeks and use PBS KIDS transmedia suites of digital games, videos, and hands-on activities, all related to early mathematics. Each transmedia suite in the intervention uses an engaging narrative throughout all components. The suites feature many preschool children's favorite media characters such as *Curious George*, *Peg+Cat*, and *The Cat in the Hat*.

The intervention model was developed over the past three years, and earlier versions were tested in two previous studies (McCarthy, Li, & Tiu, 2012; McCarthy, Li, Atienza, Sexton, & Tiu, 2013). The latest study builds on these past two studies by developing a scalable model that can be implemented in different preschool locations and by assessing the feasibility of having local preschool staff facilitate its weekly parent meetings.

Review of the Literature

The Need for Early Mathematics Support in Early Childhood

Many children in the United States do not have adequate mathematics knowledge and skills to succeed in college and career (National Research Council and Committee on Early Childhood Mathematics, 2009). Additionally, children in the United States have significantly lower mathematics scores on international assessments such as the PISA and TIMMS (Baldi, Jin, Green, & Herget, 2007; Mullis, Martin, & Foy, 2008). Research shows that prior to starting school, many children have acquired an early understanding of mathematics through their play and daily activities (Baroody, Lai, & Mix, 2006; Tudge, Li, & Stanley, 2007). However, there is growing evidence that economically disadvantaged preschool children have less extensive mathematics knowledge than their middle-income peers (Ginsburg & Russell, 1981; Hughes, 1986; Jordan, Huttenlocher, & Levine, 1994; Starkey & Klein, 1992; Starkey, Klein, & Wakeley, 2004). It has been suggested that this gap in mathematics knowledge may stem, in part, from differing levels of support for early mathematics learning in preschool and at home (Blevins-Knabe & Musun-Miller, 1996; Hart & Risley, 1995; Saxe, Gubermen, & Gearhart, 1987; Starkey & Klein, 2007). In addition, it has been found that economically disadvantaged families are less likely to provide support for mathematics development compared to their middle-income counterparts (Starkey et al., 1999). Given that early mathematics ability is a strong predictor of later mathematics achievement and overall academic success (Burchinal et al., 2011; Duncan et al., 2007; Jordan, Kaplan, Ramineni, & Locumiak, 2009), it is important to identify models, practices, and strategies to improve early mathematics competencies for all children, especially children in low-income communities.

The Importance of Family Engagement for Early Mathematics Learning

Building on the ideas of developmental psychologist Urie Bronfenbrenner (1979, 1986), there has recently been a renewed awareness that family engagement is an important element for systemic and sustained effects on learning outcomes for children (Bolivar & Chrispeels, 2011). A recent review of research, *The Impact of Family Involvement on the Education of Children Ages 3 to 8* (Van Voorhis, Maier, Epstein, Lloyd, & Leung, 2013), concludes that three types of family engagement are strongly related to mathematics achievement in young children: 1) parents' use of learning activities in the home (Jacobs & Bleeker, 2004; Pan, Gauvin, Liu, & Cheng, 2006; Starkey & Klein, 2000); 2) school outreach to engage families (Epstein, 2005; Galindo & Sheldon, 2012; Van Voorhis, 2011); and 3) supportive parenting activities, including a positive nature and quality of parent-child interactions (Blevins-Knabe, Whiteside-Mansell, &

Selig, 2007; Simpkins, Weiss, McCartney, Kreider, & Dearing, 2006). Overall, these studies suggest that including engagement activities for parents in these particular areas may help promote early mathematics achievement in their children.

Transmedia Content Provides Opportunities to Support Engagement and Learning

With increased access to computer and mobile technologies, a growing number of families with young children now have access to technology and digital media. Families with young children are increasingly accessing digital learning games, videos, and other content on computers, mobile devices, and gaming consoles (Berson & Berson, 2010; Buckleitner, 2009; Chiong & Shuler, 2010; Common Sense Media, 2013; Couse & Chen, 2010; Lisenbee, 2009). Increased access to digital content provides new opportunities for families to engage with their young children in quality learning interactions. One particular type of digital media experience that shows great promise for children's learning is called "transmedia storytelling," or "transmedia." Transmedia connotes the technique of representing a narrative or story experience across multiple platforms and formats (Herr-Stephenson, Alper, Reilly, & Jenkins, 2013; Jenkins, 2006).

Though research on learning with transmedia is still in its infancy, a number of studies have found positive impacts, including active involvement of the audience in the narrative, creation of a unified learning experience, improvement of the learning process by means of integrating knowledge and skills, and gains in student achievement (Andreu, Marti, & Aldas, 2012; Cohen, Ducamp, Kjellstrom, & Tillman, 2012; Gilardi & Reid, 2011; McCarthy et al., 2012; McCarthy et al., 2013; Pasnik & Llorente, 2013). Taken together, these studies suggest that transmedia brings particular opportunities for learning interactions that may be beneficial. These opportunities include: 1) engaging, narrative-based content that often promotes individual and collaborative play; 2) content presented in multiple modalities, allowing children to experience content in different contexts and providing multiple supports for different types of learners; and 3) the capabilities of game-based learning, including hints and scaffolds, adaptive leveling, player choice, and accessibility on various platforms.

The Intervention

The family engagement model that is the focus of this report uses the capabilities of transmedia suites along with best practices in family engagement to increase parents' capacity to support their children's early mathematics learning. The intervention focused on two overarching mathematics concepts included in the transmedia suites: numbers and operations in base ten, and shapes. The intervention lasted nine weeks and prompted parents and their children to work together on PBS KIDS transmedia activities for 30 minutes per day for four days per week, as well as encouraging parents to attend weekly parent meetings at their child's preschool.

The intervention described in this report builds upon findings from two previous RTL studies that focused on the effectiveness of the PBS KIDS transmedia suites (McCarthy et al., 2012; McCarthy et al., 2013). The current study includes those suites as part of the intervention and expands the focus to include family engagement and the possibility of scaling the intervention to reach a broader audience.

Family Mathematics Activities

Each of the nine weeks of the intervention focused on a specific mathematics concept and included four days of activities for children at home. Parents of children in the intervention group received a weekly program of PBS KIDS transmedia activities to use with their children, as well as parent support materials consisting of hands-on home activities printed from PBS KIDS Lab and a binder including summaries of the specific assignments for the days of the week. The first day of each week began with a hands-on activity, which introduced the week's mathematics concept. The second day included a hands-on activity and an online game from the transmedia suites. The third day allowed for children and parents to play three online games from the transmedia suites. The fourth day was a "free play" day, where children could elect to replay any of the online games that they had engaged with on the second and third days of the intervention week. Each activity focused on the week's mathematics concept. All hands-on activities in the program were taken from PBS KIDS Lab home activities. Appendix A shows a sample week in the parent curriculum.

During the week, intervention families accessed the intervention materials, including games and video from the transmedia suites, via Google Chromebooks they were provided with to take home for the duration of the study. A 3G data plan was provided for each Chromebook so that participants could access the Internet. The Chromebook browser and settings were configured such that participants had access only to the specific PBS websites included in the

intervention. Parents were given contact information of WestEd staff who could provide technical support and troubleshooting assistance.

Parent Discussion Groups and Staff Training for Facilitation

During each week of the study, parents or other family members[4] receiving the intervention met at their child's preschool for one hour at the end of the school day. Parents were encouraged to attend a total of nine parent meetings, one for each week of the intervention. To encourage meeting attendance, parents were sent reminder messages via flyers, weekly phone calls, and text messages. WestEd researchers arranged childcare for preschoolers while their parents attended meetings, and provided a meal for the parents and their children after the meeting. In addition, parents received a gift card at each parent meeting that they attended. During each parent meeting, parents were encouraged to describe the activities they undertook with their children the previous week, including whether they felt their children learned from those activities and what challenges they encountered.

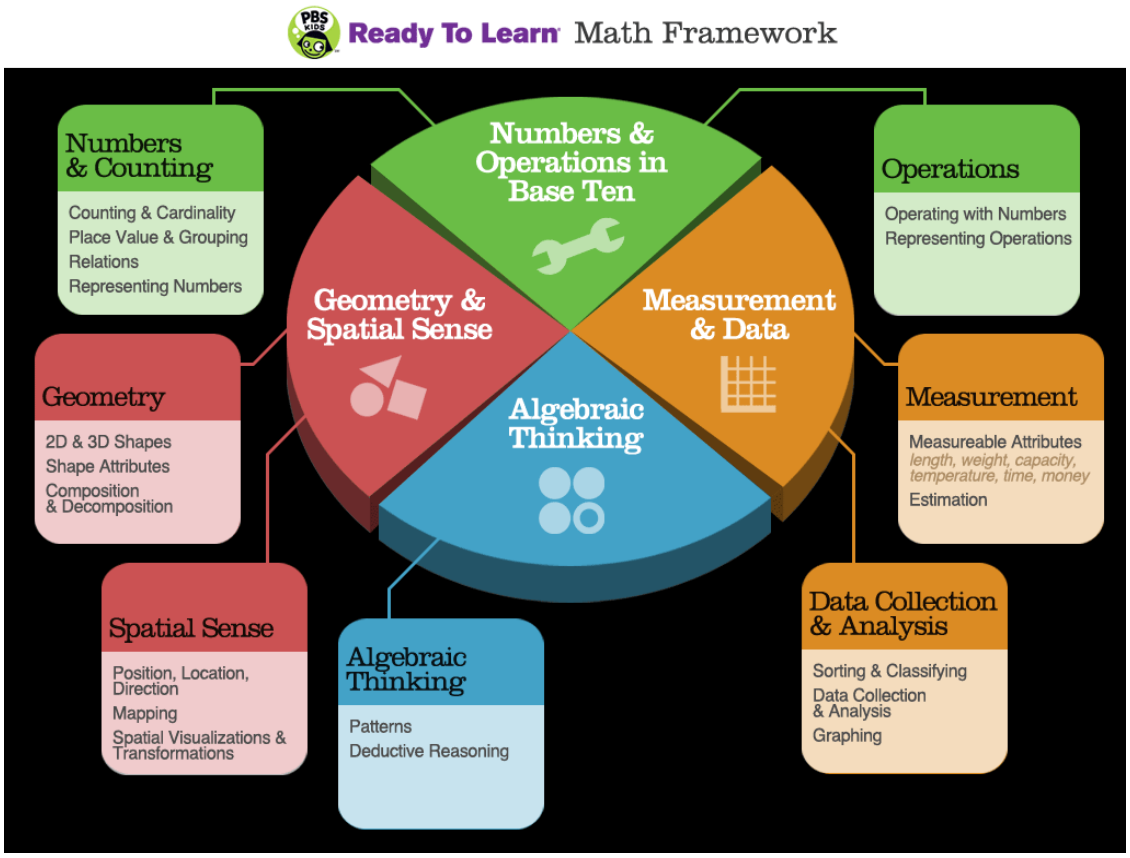
To increase the community's capacity to support children's learning and to explore the possibility of scaling the intervention to reach a larger audience, staff from the intervention preschools participated in six hours of facilitator training sessions to learn how to conduct the weekly parent meetings. The staff from the intervention preschools independently facilitated the nine parent meetings at their preschools. Parent meetings were conducted in both English and Spanish.

Transmedia Suites

All of the transmedia suites used in the study's intervention were developed under the CPB-PBS RTL Initiative and are available on PBS KIDS Lab (http://pbskids.org/lab). Figure 1 shows the specific mathematics concepts addressed by suites included in the study.

4 Other family members include grandparents, uncles, aunts, and older sibling(s).

Figure 1. Mathematics concepts presented in PBS KIDS Lab's games and support materials



The study examined an intervention that includes resources from the following five RTL PBS KIDS transmedia suites:

The Cat in the Hat Knows A Lot About That — a series designed to promote a love of learning and an interest in science in preschool-aged children, while also teaching basic mathematics skills; games cover content such as shapes, patterns, classifying, and spatial visualizations.

Curious George — a series designed to invite children to explore science, engineering, and mathematics in the world around them; games cover content related to counting and cardinality.

Dinosaur Train — a series designed to teach basic mathematics skills and build on the interest many preschoolers have in dinosaurs and trains, while learning life science, natural history, and paleontology; games cover content such as spatial reasoning, measurement, weight, volume, and sorting.

Peg+Cat — a series designed to inspire children to see math as exciting, accessible, and fun; games cover content related to numbers and operations, geometry and spatial sense, measurement, patterns and algebraic thinking, and data collection and analysis.

Sid the Science Kid — a series designed to promote exploration, discovery, and science readiness among preschoolers; games include science and mathematics content such as spatial reasoning, measurement, sorting, counting, and patterns.

Tables 1–7 describe the games and videos that were included for each mathematics topic addressed in the intervention. All games from the *Curious George* transmedia suite were available in both English and Spanish. Families were presented with both versions of the *Curious George* games and were free to play the games in the language they preferred.

Table 1. Games and Videos Related to "Counting"

Suite	Title	Learning Goals
Curious George	Bubble Pop	Count aloud by ones up to 50
Curious George	Bunny Ride	Count on by ones from a number other than 1
Curious George	Meatball Launcher	Count 1 to 5 objects upon request
Curious George	Monkey Jump	Count up to 40 with the understanding that each number is one more than the last
Peg+Cat	Counting Chickens Video	Count up to 20 with Peg, Cat, and friends
Peg+Cat	Peg's Pizza Place	Count pizza toppings, and place different toppings on pizza halves and quarters
Peg+Cat	3-2-1 Snack	Count objects and compare quantities
The Cat In The Hat Knows A Lot About That	Do You See My Seahorse?	Recognize numbers and count and add groups of objects

Table 2. Games and Videos Related to "Numbers"

Suite	Title	Learning Goals
Curious George	Apple Picking	Use number lines to identify missing numbers up to 19
Curious George	Hide and Seek	Identify numbers from 0–10 as numerals, words, and quantities
Curious George	Flower Garden	Count by ones up to 19
Peg+Cat	Counting to 20 Video	Identify numbers 1–20
Peg+Cat	Ramone Shakes It Plenty Video	Dance and identify numbers up to 20

Table 3. Games and Videos Related to "Counting Backward & Skip Counting"

Suite	Title	Learning Goals
Curious George	Blast Off	Count backward from 10 to 0
Curious George	Count with Allie	Count and represent quantities in different ways
Curious George	High Five	Count by fives up to 200
Peg+Cat	Counting by 10s Video	Count along with Peg, Cat, and friends as they collect and count space rocks by 10s
Peg+Cat	Rock Art	Count along as you pick up rocks and turn them into works of art
The Cat in The Hat Knows A Lot About That	King Cecil the Seahorse Video	Listen along as King Cecil counts and learns about seahorses

Table 4. Games and Videos Related to "Adding"

Suite	Title	Learning Goals
Curious George	Museum of Tens	Add objects to complete a set of 10
Curious George	Train Station	Add and subtract numbers up to a total of 10
Peg+Cat	10 Friends Escape the Giants Video	Count along from numbers between 1 and 9 to make 10
Peg+Cat	Four + One = Five Sleeping Pirates Video	Listen along as Peg, Cat, and friends count on from 4 to make 5
Peg+Cat	Star Swiper	Count on from numbers between 1 and 9 to make 10
Sid The Science Kid	Vegetable Harvest	Count small groups of objects
The Cat in The Hat Knows A Lot About That	Do You See My Seahorse?	Recognize numbers and count and add groups of objects

Table 5. Games and Videos Related to "Comparing & Sharing"

Suite	Title	Learning Goals
Curious George	Bug Catcher	Count and compare two sets of numbers to determine which is greater
Curious George	Fair Shares	Count and separate items into equal groups
Curious George	Ribbit	Recognize and use the addition and subtraction signs
Peg+Cat	Math in the Bath: Fair Sharing Video	Listen along as Peg and Cat count objects in the bath and tell a story about pirates
Peg+Cat	The Great Banana Has Landed Video	Count along while Peg and Cat divide the Great Banana into pieces to share with pirates

Table 6. Games and Videos Related to "Shapes"

Suite	Title	Learning Goals
Dinosaur Train	Buddy's Gem Hunt	2D shape recognition; sorting by shape, size, and color
Peg+Cat	Cat likes Circles Video	Recognize and identify basic shapes such as circles, triangles, and squares
Peg+Cat	Paint-a-Long	Combine shapes to draw Peg, Cat, and friends
The Cat In The Hat Knows A Lot About That	Sketch-a-Mite	2D shape recognition and drawing, and simple physics
The Cat In The Hat Knows A Lot About That	The Great Shape Race	Categorize increasingly complex shapes
The Cat in The Hat Knows A Lot About That	The Secret of a Good Tower Video	Get inside a termite tower and learn how the shape of the tower keeps it from falling down

Table 7. Games and Videos Related to "Advanced Shapes"

Suite	Title	Learning Goals
Peg+Cat	Chicken Blast-off	Use shapes to build a spaceship that is just the right size and shape for its passengers
Peg+Cat	Magical Shape Hunt	Count and recognize shapes
Peg+Cat	Triangle, Pentagon, Square! Video	Recognize shapes with Peg, Cat, and friends; identify patterns
The Cat In The Hat Knows A Lot About That	Huff Puff-A-Tron	Recognize shapes
The Cat in The Hat Knows A Lot About That	Kites Need Oodles of Wind! Video	Identify the different shapes of clouds in the sky

Study Design and Components

Research Questions

The study applied a combination of quasi-experimental design and qualitative observations to address several research questions. The study addressed two primary questions about the effectiveness the family engagement model featuring an activity schedule, weekly parent meetings, a school-based facilitator curriculum, and transmedia suites of digital and non-digital content:

1. Does the parent engagement model intervention increase children's knowledge and skills in mathematics?

2. Do parents' awareness and support of their children's mathematics learning at home increase after taking part in the intervention?

In addition, the study explored the effectiveness of having preschool staff facilitate the parent meetings that are part of the intervention, as having teachers in this role could increase the possibility of scaling the intervention to reach a broader audience:

3. Is it feasible for teachers from participating schools to successfully facilitate parent meetings related to the intervention?

Another goal of the study was to explore the relationship of socioeconomic status and learning outcomes:

4. How did any changes in students' knowledge and skills in mathematics relate to the students' socioeconomic status?

Intervention and Comparison Conditions

Parents and children from nine preschools were recruited to participate in the study. Participants from three preschools received the intervention, and participants from the other six preschools served as members of a comparison group.[5]

Participants in the intervention group experienced the family engagement model, which includes the family mathematics activities, parent discussion groups, and PBS KIDS transmedia suites described earlier in this report. Comparison group families used business-as-usual mathematics games, videos, and supporting materials. These materials were not provided by WestEd researchers, but were educational materials that parents would normally

5 This study was approved by an independent Institutional Review Board (IRB).

have used with their children. Comparison group parents met twice throughout the study, once during the first week of the study and again during the final week of the study. At the first meeting, parents were given a list of suggested mathematics topics to engage in with their children. These topics aligned with the skills that intervention group children practiced in the PBS KIDS transmedia suites. At the last meeting, parents were encouraged to describe what activities they had done with their children and were given several educational books to use with their children as a gift for participating in the study.

Sample Recruitment

WestEd recruited families from preschools serving economically and ethnically diverse communities in San Mateo County, California. According to the U.S. Census Bureau's 2009–2013 5-Year American Community Survey (U.S. Census Bureau, 2013a, 2013b, 2013c), San Mateo County's median household income is $88,202, and 7.6 percent of households currently live below the poverty level. To compare with other San Francisco Bay Area counties, Napa County's median income is $70,433, and Santa Clara County's median income is $91,702. Also, 25.3 percent of San Mateo County households are classified as Hispanic or Latino, and 88.6 percent of San Mateo County households have obtained a high school diploma or higher.

Parents were invited to participate in the study through the distribution of informational letters and consent forms by the preschools. The informational letters explained the purpose of the study; the study tasks, risks, and benefits; and provided contact information for the principal investigator. Both the informational letters and the consent forms were available in English and Spanish. All parents who participated in the study received the informational letter and signed a consent document for themselves and their children that described their protection under the Institutional Review Board (IRB).

A total of nine preschools were recruited and consisted of four Head Start centers, two as a part of community college campuses, and three subsidized by the California Department of Education. A total of 153 children completed pre- and post-assessment data — 71 children from three preschools in the intervention condition and 82 children from six preschools in the comparison condition.[6] Participating children were, on average, 48.6 months old at the beginning of the intervention. The majority of the children (70.9%) were Hispanic. For approximately 32.1 percent of the children, their preferred language was Spanish. Detailed equivalent test results on the intervention and comparison groups' demographic characteristics and baseline assessment scores are presented in the section on sample characteristics.

Facilitator Training

To explore the feasibility of having teachers from participating schools facilitate parent meetings related to the intervention, the researchers provided facilitator training for the staff from the intervention preschools to prepare them to conduct the weekly parent meetings at their preschools.

6 Attrition and relatively low recruitment rates at early comparison group sites necessitated recruiting additional comparison sites, which was done prior to the beginning of the intervention.

A total of eight staff from the three intervention preschools participated in the facilitator training. The staff consisted of lead classroom teachers, assistant classroom teachers, and Head Start parent advocates. At least one lead classroom teacher from each preschool participated in the training. The staff members participated in multiple training sessions for a total of six hours of facilitator training. WestEd researchers and professional development providers created the curriculum for the facilitator training and conducted each of the training sessions.

The facilitator training included numerous topics related to the intervention, with each session building upon the knowledge and skills gained in the previous session. Topics included: the weekly mathematics curriculum, including hands-on activities and online games and videos; general facilitation tips and best practices; how to use study technology, such as the study website; and meeting and site logistics. The training also explored mathematics pedagogy, milestones in the development of mathematical thinking for young children, and the progression of math learning through the PBS KIDS Math Skills Wheel (available on PBS KIDS Lab). Further, the training explored a variety of best practices related to the intervention, including techniques for facilitating a bilingual parent meeting, strategies to sustain children's engagement during intervention activities, strategies to help young children learn mathematics, strategies to encourage parents' involvement and support of their children, and strategies for creating positive experiences around mathematics for both parents and children.

In early training sessions, WestEd researchers modeled the facilitation of an abridged version of a typical parent meeting for the preschool staff, with WestEd researchers role-playing as the meeting facilitators and with preschool staff role-playing as parents present at the meeting. As the training sessions continued, the preschool staff became more comfortable with the parent meeting structure and facilitation techniques. The preschool staff then began to role-play as the meeting facilitators and facilitated a single activity during the training session, with WestEd researchers role-playing as parents. Following this, the preschool staff and WestEd researchers debriefed the activity together and WestEd researchers provided the preschool staff with constructive feedback and tips. This gradual increase of responsibility continued until the last training session, when the preschool staff facilitated an abridged version of an entire parent meeting.

Baseline and Outcome Measures

The following two tests were given to students in both the intervention and comparison groups before the intervention began and again after the intervention was completed. They were used to test the baseline equivalence between the intervention and comparison groups and served as covariates in the outcome analyses. The survey measures and focus groups described after the tests below were used to gather more baseline information, such as the demographics of participants and outcome data, such as parents' support for their children's mathematics learning and parents' perspectives on the intervention.

Test of Early Mathematics Ability (TEMA-3)

The Test of Early Mathematics Ability, third edition (TEMA-3) is a primary test of children's informal and formal mathematics knowledge, developed by Western Psychological Services. It is a standardized, nationally normed achievement test that has been found to be a valid and reliable measure of the mathematics concepts that it covers (Ginsburg & Baroody, 2003). The test is designed for use with children ages 3 through 8. It measures four categories of informal

mathematics: Numbering, Number Comparisons, Calculation, and Concepts. It also measures four categories of formal mathematics: Numeral Literacy, Number Facts, Calculation, and Base 10 Concepts. Table 8 provides a description of each category of informal and formal mathematics. The test contains 72 items in two forms. The TEMA-3 is not a timed test — no precise time limits are required for children being tested. Depending on children's mathematics ability, children will be able to complete all 72 items or the relevant portion of the test. On average, it takes 45–60 minutes to administer. The TEMA-3 was used as a primary pre/post measure for student learning.

Table 8. Description of categories of informal and formal mathematics in TEMA-3

	Description of the Categories
Numbering	Pre-counting numbering abilities: e.g., children learn to recognize collections of one or two items and label them "one" and "two."
Number Comparisons	Comparing two or more collections: e.g., children learn the term *more* and use it to label the larger of two collections that obviously differ in number.
Calculation	Mentally and nonverbally adding two small, previously viewed collections; solving word problems with sums up to 12 by counting or reasoning: e.g., after seeing one item covered and a second item slipped under the cover, children can determine the sum and indicate their answer by producing two items.
Concepts	Determining key aspects of understanding that underlie number and calculation skills at the counting phase: e.g., children learn that a whole is the sum of its parts and that the whole is larger than any single part.
Numeral Literacy	A major transition in children's ability to represent numbers involves the ability to read, write, and understand numerals: e.g., children learn that the numeral 2 is read aloud as "two" and conversely that the spoken word "two" is written as 2.
Number Facts	Mastery of the basic number combinations and ability to quickly generate the answer to single-digit addition, subtraction, and multiplication facts: e.g., children have learned that 2 + 0 = 2 and 3 + 0 = 3; they may extract a principle to the effect that adding zero to any number does not change it.
Calculation	Addition and subtraction accuracy: e.g., children can talk aloud as a problem is being solved and can justify their procedure.
Base 10 Concepts	Grouping by 10: e.g., children understand that when one carries, one is really regrouping by units of 10s, 100s, and so on.

Researcher-Developed Assessment

Given that the TEMA-3 tests only children's numerical sense, WestEd researchers developed a measure of mathematics skills that addressed the remaining mathematics concept that is presented in the transmedia suites: shapes. The researcher-developed assessment of mathematics skills includes eight items that measure the early mathematics concept of shapes using items from, and adapted from, the Child Math Assessment (Klein & Starkey, 2006). The assessment is not a timed test — no precise time limits are required for children being tested. The researcher-developed assessment was administered immediately prior to the administration of the TEMA-3. On average, it takes about five minutes to administer the assessment. The scores from the researcher-developed measure of mathematics skills were calculated by summing the number of items scored as correct. The scores range from 0 to 8. The eight items showed good reliability on the pre-test (alpha = .84) and on the post-test (alpha = .82).

Home Learning Environment Survey for Parents

Researchers collected six types of family demographic information from both implementation and comparison groups: preschooler's age, race/ethnicity, preferred language, parent education level, number of people in household, and total household income. In addition, researchers collected information on parents' awareness of their child's mathematics learning and parents' support of their child's learning through home activities. Information on these topics was gathered by using two scales adapted from the Home Learning Environment (HLE) survey (Starkey et al., 1999). The HLE survey is a parent survey of home mathematics activities that was developed for use with 3- and 4-year-olds and is available in English or Spanish. The survey includes three sections. The first section is a demographic section that acquires parents' education, ethnicity, preferred language at home, relationship to the child, number of people in the household, and total household income. The second section obtains parents' awareness of their children's mathematics development. The third section asks parents to report on the types of activities their children engaged in during the previous week and how frequently their children did each activity alone, with another child, and with an adult. Researchers collected baseline data during the months of May, June, July, and August of 2014, and collected outcome data at the conclusion of the intervention during the months of July, September, and October of 2014.

Researchers calculated parents' awareness by using the composite sum score of participants' responses on the HLE survey section related to parents' knowledge of preschool children's mathematics abilities and skills. Parents' support for learning at home was determined by using the composite sum score of participants' responses on the HLE survey section addressing educational resources and activities in the home environment and was an indicator of parents' actual support of their children's mathematics learning.

Participant Focus Groups

All parents or other caregivers in the intervention group were invited to take part in a focus group. About 95 percent of the families in the intervention group were represented in the focus groups. Eleven focus groups were conducted across all of the intervention sites after the final week of the intervention. Four to six intervention parents participated in each focus group. Parents were asked to describe their children's mathematics curriculum in preschool, how they used intervention materials with their children, how their children responded to the materials, and whether the

materials were helpful for their awareness and support of their children's mathematics learning at home. The focus groups were conducted in either Spanish or English, and each lasted 30 minutes.

Implementation Measures

Data from the following measures were collected during the intervention and used to determine implementation fidelity — that is, to gauge how fully and accurately the intervention was actually implemented. Several studies have shown that assessing implementation fidelity is critical to understanding how programs are implemented as well as how programs transition from research settings into "real world" settings (Durlak & DuPre, 2008; Harachi, Abbott, Catalano, Haggerty, & Felming, 1999). Accordingly, during each week of the intervention period, researchers collected data from two measures — teacher reflection logs and meeting observations — to assess the implementation fidelity of the parent meetings as facilitated by the participating preschool staff. These measures were used to assess adherence to the core components of the intervention model, and exposure (i.e., dosage) to the program in relation to the amount prescribed by the intervention model (James Bell Associates, 2009).

Weekly Fidelity Survey

Each week, all intervention parents were asked to respond to survey questions about their activities during the previous week including: (1) which activities/games they played with their children, and (2) how long their children played the activities/games. See Appendix B for a sample weekly fidelity survey. WestEd researchers tracked the completion of the weekly fidelity survey along with parent attendance and receipt of gift card on a sign-in sheet completed at each parent meeting.

Electronic Usage Logs

The Chromebooks and a custom WestEd website were configured to track activities and log when participants accessed the PBS KIDS transmedia suites, which games and videos from the suites were accessed, and approximately how long participants used each game. The custom PBS/WestEd website used a login system connected to Google Analytics. Each time participants logged into the custom website to access the PBS KIDS games and videos, their username was identified within Google Analytics. This allowed researchers to identify usage data from study participants. Data was downloaded from Google Analytics and compiled by WestEd researchers.

Researcher Observations of Fidelity of Parent Meeting Implementation

At each weekly parent meeting, a trained WestEd researcher observed how the meeting facilitators implemented the intervention, noting whether facilitators used appropriate delivery methods and engaged participants during the meeting. The observation protocol was tailored to the week's mathematics content and corresponding PBS KIDS Lab online games and hands-on activities. The observation protocol also included a Likert-type rating scale to evaluate the fidelity of implementation of the core components of the program model and open-ended responses to document the overall meeting implementation and specific modifications made to each of the core components (James Bell Associates, 2009). WestEd researchers attended a comprehensive training, which defined each of the core components of the intervention and outlined the observation rating and note-taking procedures.

Weekly Teacher Reflection Logs

Weekly teacher reflection logs allowed for ongoing assessment of implementation fidelity. Each week, the participating teachers and staff were asked to complete reflection logs describing their facilitation of the parent meeting held at their preschool site. The purpose of the teacher reflection logs was to document the content and activities covered in the weekly meeting and whether and how teachers adapted the facilitation of the parent meeting to better meet the needs of parents at their site (Sanchez et al., 2007). Participating teachers and staff were asked to rate their level of implementation for each core component of the parent meeting as prescribed by the facilitator guide and to include detailed notes about any modifications made during the week's parent meeting.

Data Quality Assurance and Data Analysis

Certified TEMA assessors administered the TEMA-3 to the children. All assessors were trained and certified to give the TEMA-3 and to score the assessment results. Parent meeting facilitators were trained on the procedures for collecting the HLE survey and the weekly fidelity surveys. Weekly parent meeting observers were trained on how to complete the fidelity notes rubric. Individuals who led focus groups were trained on the focus group protocol, as well as techniques for ensuring maximum participant involvement.

Several steps were taken to ensure high response rates for the outcome measures. The participant consent forms distributed at the beginning of the study informed parents of the timeline for data collection for children. During the final parent meetings, facilitators reminded the parents of the timeline for the post-measures. Researchers also communicated frequently with parents, preschool directors, and teachers to identify any potential changes in a child's or parent's participation in the program.

The study used a two-level Hierarchical Linear Model (HLM) to investigate the promise of the family engagement model on children's outcomes after accounting for the pre-existing differences between the intervention and comparison groups as gauged by the pre-intervention baseline measures. HLM takes into account the nested structure of the data — students nested within preschool sites — to estimate intervention effects (Murray, 1998; Raudenbush & Bryk, 2002).

Several approaches were utilized to address missing data. For outcome measures, missing item responses were treated as incorrect responses. Participants who missed 20 percent of the items in the outcome measures were removed from the corresponding analyses. Participants who had more than 20 percent of missing data on the covariates were also removed from the outcome analysis.

Baseline Characteristics of Sample

The target age group of the study sample was preschoolers ages 3–5 and their parents. Nine preschool centers in San Mateo County, California, agreed to participate in this study (three in the intervention group, six in the comparison group). Complete pre- and post-assessment data were collected from 153 children. The intervention and comparison groups did not differ significantly from each other in terms of age, parent education level, or poverty level.[7] However, more children in the intervention group than the comparison group were Hispanic (88.73% vs. 60.98%) (Table 9).

Table 9. Participant demographic information

Demographic Characteristic	Intervention		Comparison		
	Number	Percent [a]	Number	Percent	p-value [b]
Parent education					0.058
High School or Less	32	45.71%	16	21.92%	–
Some College or Technical School	29	41.43%	23	31.51%	–
AA Degrees	3	4.29%	10	13.70%	
Bachelor's Degrees	4	5.71%	18	24.66%	
Graduate Degrees	2	2.86%	6	8.22%	
Low-income					0.088
No	18	27.27%	33	45.83%	–
Yes	48	72.73%	39	54.17%	–
Ethnicity					0.046*
Hispanic	63	88.73%	50	60.98%	–
Non-Hispanic	8	11.27%	32	39.02%	–
	Mean	**Standard Error**	**Mean**	**Standard Error**	**p-value [c]**
Age (Month)	48.98	0.99	48.30	0.82	0.60

* *Significantly different from zero at the 0.05 level.*

7 In this study, low income was defined by dividing family income by the U.S. poverty threshold for a particular family's size. For example, the poverty threshold for a family of three was $19,790 in 2014.

a. Computed based on valid (non-missing) data. Components may not sum to 100 because of rounding.

b. A test for equality of proportion between intervention and comparison students was conducted; the corrected p-value, accounting for clustering effects (children were nested with preschools), is reported here.

c. A multi-level regression model that accounted for clustering effects (children were nested with preschools) was used to test whether children's age was equivalent between intervention and comparison groups.

Table 10 shows the baseline equivalence comparisons on TEMA-3 and the researcher-developed assessment. There were no significant differences between intervention and comparison groups on pre-test TEMA-3 scores. However, intervention and comparison groups showed significant differences on the pre-test of the researcher-developed assessment, with the comparison group scoring higher on the assessment than the intervention group.

Table 10. Children's baseline assessment results

Measure	Intervention	Comparison	Difference [ab]	p-value
TEMA-3				0.68
Mean	17.55	18.94	-1.39	–
Standard Error	2.63	2.16	3.40	–
N	71	82	–	–
Research-Developed Assessment				0.05*
Mean	0.68	1.42	-0.74	–
Standard Error	0.29	0.25	0.38	–
N	71	82	–	–

* *Significantly different from zero at the 0.05 level.*

a. A multi-level regression model that accounted for clustering effects (children were nested with preschools) was used to test whether children's baseline TEMA-3 results were equivalent between intervention and comparison groups.

b. Margin of differences for baseline TEMA-3 and researcher-developed assessment were 0.11 and 0.35, respectively.

Table 11 shows the baseline equivalence test on each individual researcher-developed assessment item. No intervention and comparison group differences were apparent on the individual pre-test shape recognition items, except for the recognition of oval ($p = 0.02$).

Table 11. Baseline researcher-developed assessment results

Shape Recognition	Intervention		Comparison		
	Number	Percent [a]	Number	Percent	p-value [b]
Circle					0.47
Incorrect	57	80.28%	59	71.95%	–
Correct	14	19.72%	23	28.05%	–
Square					0.17
Incorrect	67	94.37%	71	86.59%	–
Correct	4	5.63%	11	13.41%	–
Triangle					0.11
Incorrect	62	87.32%	58	70.73%	–
Correct	9	12.68%	24	29.27%	–
Rectangle					0.18
Incorrect	69	97.18%	75	91.46%	–
Correct	2	2.82%	7	8.54%	–
Trapezoid					0.42
Incorrect	62	87.32%	65	79.27%	–
Correct	9	12.68%	17	20.73%	–
Pentagon					0.57
Incorrect	63	88.73%	69	84.15%	–
Correct	8	11.27%	13	15.85%	–
Octagon					0.08
Incorrect	71	100%	73	89.02%	–
Correct	0	0.00%	9	10.98%	–
Oval					0.02*
Incorrect	67	94.37%	70	85.37%	–
Correct	4	5.63%	12	14.63%	–

* *Significantly different from zero at the 0.05 level.*

a. Computed based on valid (non-missing) data. Components may not sum to 100 because of rounding.

b. A test for equality of proportion between intervention and comparison students was conducted, and the corrected p-value, accounting for clustering effects (children were nested with preschools), is reported here.

Table 12 shows the baseline equivalence test on parents' awareness of children's mathematics development and parents' support for learning at home. No intervention and comparison group differences were apparent on the pre-survey answers.

Table 12. Parents' awareness and support for learning baseline results

Measure	Intervention	Comparison	Difference [a]	p-value
Parent Awareness				0.65
Mean	10.72	10.99	-0.27	–
Standard Error	0.43	0.41	0.59	–
N	70	75	–	–
Support for Learning				0.09
Mean	14.78	16.29	-1.51	–
Standard Error	0.64	0.62	0.89	–
N	70	75	–	–

a. A multi-level regression model that accounted for clustering effects (children were nested with preschools) was used to test whether children's age was equivalent between intervention and comparison groups.

Study Results

Fidelity of Implementation at the Intervention Site

Analysis of fidelity data — from researcher observations and from teacher reflection logs — indicates that generally fidelity of implementation during the parent meetings was high. Deviations from the suggested time schedule occasionally occurred due to issues such as slow load times because of poor connectivity at the school site and additional time spent translating English game instructions into Spanish. Appendix C shows the typical agenda and timeline for parent meeting facilitation and additional details around fidelity of implementation at parent meetings.

Fidelity of Implementation at Home

Review of parent fidelity surveys and analysis of parent focus group data and of electronic usage logs suggest that families implemented intervention activities at home as prescribed by the intervention. Parent self-report on the weekly fidelity surveys and in focus groups suggests that families interacted with the digital and hands-on games and activities for approximately 30 minutes a day, four days a week, over the course of the intervention. Electronic usage logs were collected during seven weeks of the study (week 2 through week 8). On average, families played the online games and viewed videos two or three days each week. Families interacted with the digital assets in the intervention, playing online games and viewing video approximately 2.3 hours per week.

Children's Knowledge and Skills in Mathematics Improved

The quantitative assessment data (from TEMA-3) indicate that the intervention was positively associated with gains in children's knowledge and skills in mathematics. Adjusted mean differences on TEMA-3 scores show that the intervention group's scores on the post-test were higher on average than those of the comparison group (point estimate of 2.93; minimum detectable effect size [MDES] = 0.22).[8] This difference was statistically significant (at the 0.05 level) after accounting for differences in baseline test results and participant ethnicity (see Table 13). The intervention group had significantly lower scores on the baseline researcher-developed assessment focused on the concept of shapes. After the intervention, the intervention group's combined mathematics scores related to shapes were similar to

8 Effect size was calculated by dividing impact estimate by the comparison group unadjusted standard deviation of the outcome variables (standard deviation [*SD*] = 13.18 for TEMA-3, *SD* = 2.18 for researcher-developed assessment).

those of the comparison group as measured by the post-assessment of shapes. The difference (MDES = 0.20) between intervention and comparison groups' scores falls within the accepted margin of differences (MDES < 0.25).[9]

Table 13. Analysis of student outcomes

	Adjusted Mean						
Measure	Intervention (Standard Error)	Comparison (Standard Error)	Difference (Standard Error)	MDES	*p*-value	95% Confidence Interval	Sample Size
TEMA-3 (Experimental Scores)	24.68 (.99)	21.74 (.92)	2.93* (1.39)	0.22	.035	0.21 – 5.65	153
Researcher-Developed Assessment	1.82 (.20)	1.40 (.19)	0.43 (.28)	0.20	0.13	-0.13– 0.98	153

* *Significantly different from zero at the 0.05 level.*

Note: Data were regression-adjusted using multi-level regression models to account for differences in baseline characteristics.

Though only two weeks of the intervention focused on shapes, intervention group children grew in their understanding of basic and advanced shapes. Descriptive analysis of intervention children's scores on the researcher-developed assessment of shapes indicated that there were significant improvements in the number of children correctly recognizing circle (19.72% in pre vs. 25.35% in post, p=0.035), triangle (12.68% in pre vs. 25.43% in post, p=0.040), trapezoid (12.68% in pre vs. 26.76% in post, p=0.009), and pentagon (11.27% in pre vs. 28.17% in post, p=0.005).

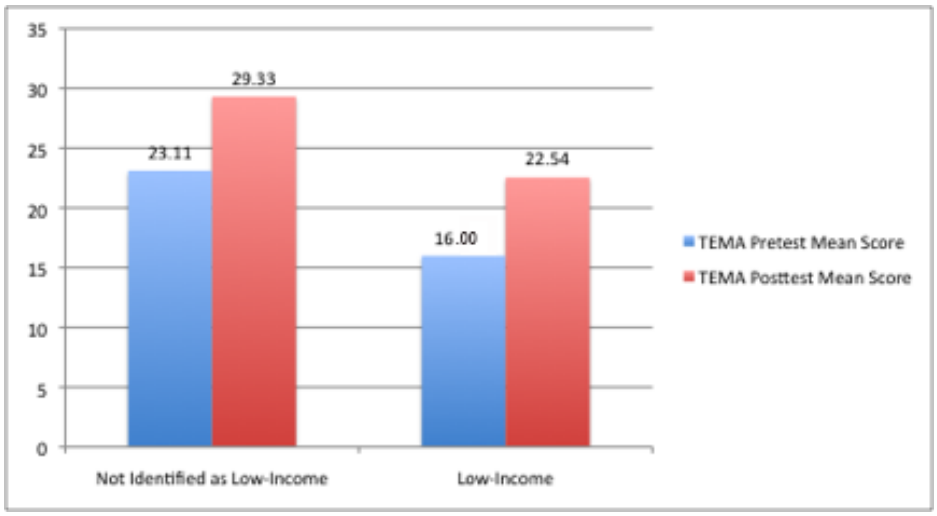
All Socioeconomic Levels Improved in Mathematics

The analyses indicate that intervention group children at all income levels increased in their mathematics ability. A descriptive analysis of the intervention group data indicates that TEMA-3 scores increased on average more than six points for children identified as low-income *and* for those not identified as low-income.[10] Figure 2 shows the pre– and post–TEMA-3 assessment score average for both socioeconomic groups within the intervention students.

9 According to the *What Works Clearinghouse Procedures and Standards Handbook* (Institute of Education Sciences, 2014), the accepted margin of differences is less than 0.25 SD.

10 Possible experimental scores range from 0 to 210.

Figure 2. Pre and post TEMA-3 assessment intervention group score averages



These findings indicate that the intervention has promise for boosting children's mathematics abilities at all income levels. Of particular interest, quantitative and qualitative data analyses show that low-income children's mathematics ability improved during the intervention, moving them closer to being ready for kindergarten.

Parents' Awareness of Their Children's Mathematics Learning Increased

Analysis of quantitative data suggests that the intervention parents grew significantly in their awareness of their children's mathematics learning. To detect whether the family engagement model increases parents' awareness of their children's mathematics learning at home, researchers analyzed the composite sum score from the HLE survey items related to awareness of mathematics. The survey items ask parents about their knowledge of preschool children's mathematics abilities and skills. The results indicated that intervention parents' awareness of their children's mathematics learning significantly increased over the course of the intervention in contrast with comparison parents' awareness (point of estimate of 1.55, effect size = 0.30) (Table 14).

Table 14. Analysis of parents' awareness of mathematics learning

	Adjusted Mean						
Measure	Intervention (Standard Error)	Comparison (Standard Error)	Difference (Standard Error)	MDES	*p*-value	95% Confidence Interval	Sample Size
Parent Awareness of Child Math	13.88 (0.57)	12.33 (0.46)	1.55* (0.74)	0.30	0.036	0.10 – 3.01	153

* *Significantly different from zero at the 0.05 level.*

Note: Data were regression-adjusted using multi-level regression models to account for differences in baseline characteristics.

Parents' Support of Their Children's Mathematics Learning Increased

Analyses of the quantitative data also suggest that intervention parents increased their use of activities and strategies to support their children's mathematics learning. Researchers analyzed the composite sum score from the HLE survey items related to parents' support for learning at home. The score includes 28 survey items about the availability and use of books, store-bought games, educational technology, and other educational resources in the home. The quantitative data analyses indicate intervention parents' support of learning at home surpassed that of comparison parents with an effect size of 0.71 (Table 15).

Table 15. Analysis of parents' support for learning at home

	Adjusted Mean						
Measure	Intervention (Standard Error)	Comparison (Standard Error)	Difference (Standard Error)	MDES	*p*-value	95% Confidence Interval	Sample Size
Parent Support for Learning at Home	18.77 (0.52)	16.50 (0.50)	2.27** (0.75)	0.71	<0.01	0.80 – 3.74	153

** *Significantly different from zero at the 0.05 level.*

Note: Data were regression-adjusted using multi-level regression models to account for differences in baseline characteristics.

Themes from Qualitative Data Analysis

Researchers analyzed the qualitative data to generate themes, using a combination of grounded theory (Strauss & Corbin, 1990) and established methods for coding qualitative data (Miles & Huberman, 1994) to identify and categorize the participants' responses. Throughout the process, researchers used peer debriefing and auditing to check codes and concepts. Identified codes and concepts were further sorted to generate categories. Categories were further reduced to produce the themes described below that emerged from the qualitative data.

Parents Reported Increases in Children's Knowledge and Skills in Mathematics

Analysis of qualitative data from the parent focus groups indicates that, over the course of the intervention, parents noticed growth in their children's understanding of the intervention's targeted mathematics concepts. Nearly all parents taking part in the 11 focus groups mentioned that they observed their children learning new mathematics content. The following quotes are typical of the majority of intervention-group parents who participated in focus groups.

> *He learned a lot. He learned to add small figures, less than ten. Before, he didn't know any adding. He now knows the numbers up to 12 and he also identifies shapes.*
>
> *I definitely think he learned. Before, he would skip numbers. He would start counting really fast. He takes the time to count better now. I know he understands because we've played a lot with the [manipulatives]. If I take objects away, [he understands] there is less. If I put some more, [he understands] there's more.*
>
> *It [the intervention] is going to help them, especially when they go to kindergarten. It'll be a lot easier for them.*

Parents also reported that their children grew in their ability to identify shapes.

> *When I go to the store he comes with me and he can distinguish the colors and the different fruits, the shapes of the fruits.*
>
> *My daughter, I believe she made many changes, like now she knows all of the shapes that they have to look for, like hexagons, octagon. This class was very fun for her.*
>
> *She learned all the shapes, she learned a lot of shapes, the names and everything. Before, there were ones that she didn't know. She just knew the circle, the basic ones.*

A parent also reported that she learned the names of shapes, which in turn helped her support her child.

> *It also helped me, because I only studied up to 9th grade, so sometimes we don't know how to teach our kids. So, I also learned the names of the shapes, like [table neighbor] said, I no longer recalled the hexagon, the pentagon and the octagon, the oval and what's the name of the one that is crooked? Trapezoid.*

Several parents mentioned that their children with special needs benefitted from the program.

> *I'm very thankful because it [the intervention] is something very creative and useful for our kids. I was very glad that my kid was part of the program. My son has [a disability]. In fact, with this, he learned to count. It has helped me a lot to teach him to count cars, steps, whatever. He doesn't know [everything] perfectly well but it has helped him a lot.*

Parents' Awareness of their Children's Mathematics Learning Increased

Results of quantitative coding of focus group transcripts indicated that parents described or demonstrated an increased awareness of their children's process and ability to learn mathematics. This suggests that parents grew in their awareness of their child's mathematics learning. The quote below is typical of the detailed descriptions provided by parents of their children's mathematics knowledge. In this quote, a parent demonstrated a precise assessment of his child's knowledge of geometric shapes.

> *He learned almost all the shapes except he still gets confused with hexagon, pentagon and octagon. He only gets confused with those three, but he knows how to count the sides, he knows how many sides it has.*

Many parents also expressed surprise that their child could learn mathematics during their preschool years.

> *Sometimes I thought, my kid's too little to know that. But, well he learned it, so it must not be that hard.*

> *[My child] has improved so much. I never thought he was going to know his numbers and there was one [game] where it was an architecture type thing. I didn't think he would figure that out. I thought that was going to be the hardest obstacle for him. I was dreading the moment when I would have to explain everything to him. But he got on the computer and started doing it by himself. I doubted him, and then was like, "Oh, I shouldn't have doubted him, because he knows so much!*

> *This [intervention] makes you think that even though they're so young, their minds are growing and they're really smart and they catch onto everything. [They are] building on everything.*

Parents Refreshed Their Own Knowledge of Mathematics

Many parents mentioned that the intervention had refreshed their understanding of mathematics, helping them learn or re-learn mathematics concepts. They mentioned this led to an increased

awareness of the mathematics concepts their children were learning at home and school. Below is a typical quote in this coding category.

> *I didn't have a program like this when [my other kids] were younger, and I didn't do math at that age. It [the intervention] helped me a lot with math.*

Parents Integrated Mathematics Learning Throughout the Day

Qualitative data also indicate changes in parents' level of interaction with their children around math. Nearly all intervention parents mentioned they grew in their ability to support their child's mathematics learning, including by integrating more frequent mathematics dialogue and activities throughout the day.

> *Now it's more in my head for how to [help] her to learn. Like, we'd be around the house, 'Do you know what shape this is?,' and she'll say, 'Square!' And I now I'm trying to figure out a way for her to get to 3-D from the flat. So I tell her, 'It looks like a square at the bottom and on the top and the side, but you can put something inside. It's not flat.' I say, 'It looks like a square but can you put something inside?' She'll say, 'Yes,' so I'm like, 'Well, what shape is it then?' She says, 'A cube.'*
>
> *I learned lots of activities. We go in the car and I tell him, 'Look, one car, two, three,' both in English or in Spanish, but I'm always repeating the numbers. When I see something I tell him, 'It's a square, it's an oval,' and even though he can't always say it, he is still listening to it.*
>
> *While I play with him he's learning.*
>
> *We started counting everyday objects. When we go out, or we go to the grocery store, I say, 'Can you find me a thing of bananas that has five bananas on it, one for each of us?' She'll count the bananas and find the one for each of us. Stuff like that.*

Parents Learned New Skills, Becoming Better Prepared to Support Their Children's Learning

The majority of intervention parents in the focus groups mentioned that they learned new skills and strategies from the intervention that allowed them to enrich their learning interactions with their children. Parents mentioned they were excited about their new skills, and highly motivated to continue supporting their children long past the intervention.

> *It [the intervention] was good because it helped me to consciously think more about asking her questions, about counting and colors and shapes and stuff like that. Which I did before, but I didn't consciously do it as often as I would do now. Like, everyday objects that pass us by throughout the day.*
>
> *The program provides a set of tools for us to teach our kids. Before, we didn't have these tools. Sometimes we would think, ' How can I teach the numbers to my child?' So, it's a set of tools that is essential for all parents to continue to teach their children. Unfortunately, we didn't have them before, but this program provides them.*

Another group of parents said participating in the intervention opened their eyes to the importance of supporting their children's mathematics learning.

> *It [the intervention] just made me think. It kind of opened a door for me, that I could teach them this and I could teach them that. Even though they're little, they're really smart and they catch on fast to everything, and you can take that further.*

> *I realized that if you have the tools, you can teach the child. And the child sees that his father sits down with him, so this must be something important. Furthermore, you develop the knowledge in the child that education is important, because he sees that even his father sits down with him to learn, he stops doing other things to be with him. So, this motivates him to learn. I think this is a set of tools provided to us so that we can educate our kids. If the parents don't have those tools it's a little bit more difficult. This program made things easy for us.*

> *It's a different way of learning. In our country [of origin] we had studies like one plus one, one plus two. We didn't have different activities or games. There we had to learn by repetition. It [the intervention] showed us how we can help our child everywhere. Our home is a school for our kids. If we go to the store, if we go to the park, we can say: 'What color is the tree?' 'What change [money] is there?' They [the teachers] provided lots of ideas to us. I really liked it.*

Many parents mentioned that they felt the intervention prepared them to support their children's mathematics learning after the intervention ended.

> *This program is mainly a guide to continue supporting him. They provided us with a lot of materials to continue working with him so I feel supported to move forward.*

Parents Set Aside Time Each Day to Focus on Learning

About a quarter of the parents in focus groups said that the intervention motivated them to spend time with their children and focus on mathematics learning.

> *It [the intervention] motivated me a lot. Before, I wouldn't often sit with my daughter to teach her. This program motivated me to spend more time with her, to teach her more, to dedicate myself to her more, for learning. Because sometimes we get home, and we don't give them that much attention, and she would show me a little project and I would say, 'How nice.' But with this program, makes you get motivated, to give yourself more time for them, so that they can learn more. I really think that if this program didn't exist, my daughter wouldn't have learned about triangles, rectangles, or even counting, because we learned how to show them.*

> *It helped us out a lot with mathematics. It helped me, really, because it motivated me a lot so that I could try to teach my son. I've always liked to try to teach my children the little that I know, but the program motivates you a little bit more to do it. I enjoyed it a lot. This [intervention] helped me. It takes me to the next step to help him keep progressing in all those [math] areas.*

> *The thing is, this program motivated us.*

Results of qualitative data analysis also suggest that parents learned to set aside a period of time each day to support their child's mathematics learning.

> *So that they can succeed, I learned that you must dedicate at least 15 or 20 minutes to them because it's very important for them and they learn very quickly. Sometimes I increased those 15 or 20 minutes, I dedicated him up to one hour.*

> *Now we put aside more time to our children. Before we didn't do it because we didn't have enough time and now we feel more interested in spending at least half an hour or more with them.*

Parents Began to Target Learning Interactions

A majority of parents said they grew in their ability to focus learning interactions with their children on the specific areas of mathematics.

> *I learned that we play with them and they learn. For example, I learned that for [counting] backwards, when he goes to sleep I have to tell him, 'I'm going to turn the light off, ten, nine, eight…' so I count backwards and he listens to that every night and it's a game for him and for myself, but it's a way he can learn things.*

In addition, several parents said they remembered from week to week which topics their children had struggled with, and would go back to review those topics.

> *For the topics or the things that she struggled with more, those were the ones we go back to. For instance, she could count to 20, and then from there she would forget. I'll be like, '21,' then she'll get the pattern, 22, 23. She'll go on. Then she would get to 29, and then I would have to help her, now it's 30. One day we sat on the floor and we were throwing the ball to each other, and we were like, '1, 2,' or whatever, and we counted to 100. I said, 'Let's see if we can count to 100,' and she did it.*
>
> *She likes it when I test her. I'll be like, 'You know, the counting by fives? Remember the fives?' We'll go back to the [game] and see what score she gets. I'll be like, 'Okay, I'm going to do a test. Go!'*

Parents Worked Collaboratively with Children to Provide Context-Sensitive Support

Analyses suggest that many parents learned a new way to actively participate in learning activities with their children and provide support to their children when necessary.

> *I learned I can teach my son so that he can learn, and we did a lot of work together. When I worked with him we cut, we colored. He colored a little less than I did because he let me color more and he would say, 'You can do it Mommy.' But I would color more so that he could keep working on [the math task]. So some parts I would do, and some parts he would do, but we were both working on it.*
>
> *For me, with my daughter, it was fun. The best thing for us was about doing the activities together, and to show her how to learn. I learned how to ask her more questions. It was fun because we found a way to learn together.*

Parents Gravitated to a Learning Environment that Encourages Playfulness and Positive Affect

Another concept that emerged during analysis is that of playfulness and positive affect. Many parents reported they increased their use of fun, games, and playfulness to more deeply engage their children during learning interactions. The following quotes illustrate parents' realization that positive encouragement and adding an element of play would motivate their children to stay engaged in the mathematics content.

I realized sometimes I have to tell him, 'Okay let's do this for a little bit longer,' or I might need to make it fun and exciting, like an adventure, like, 'Look! Oh my gosh! Look at this!'

Sometimes I'd tell him I didn't know, and he'd say, 'It's this one.' I would act like I didn't know so that he could tell me, and he would do it, and he liked the things that he was doing.

I would act like I didn't know, and he would do it fine, and he would laugh at me because he'd say, 'I beat you, you didn't know!' But I would let him win so that he could keep trying, and if he couldn't do something, he would say, 'Mom…' and I would say, 'You can. You know! ' I told him, 'If every person couldn't do anything then we would all be stuck. Keep trying.' So he would try once again, and he would be able to do it, and he would smile.

Teachers Were Successful at and Enjoyed Facilitating the Parent Meetings

Data regarding fidelity and teacher interview data suggest that preschool teachers at the intervention sites were successful facilitators of parent meetings. A key aspect of the intervention model was to train preschool teachers to facilitate the intervention parent meetings at study preschools. Creating a model where teachers facilitate parent meetings is important for scaling up the intervention so it can take place at a large number of schools. Before the study, it was not known if preschool teachers could use a facilitator curriculum to facilitate parent meetings over a nine-week period. An analysis of fidelity data, including notes taken during parent meetings and debriefing conversations with preschool teachers after the intervention, indicates that teachers were very effective in their roles as parent meeting facilitators. Not only did teachers deliver intervention activities with fidelity, they provided parents with a deeper connection to the preschool.

Nearly all teachers reported they enjoyed the experience of teaching parents. In particular, they enjoyed seeing parents grow in their awareness of and ability to support their children's mathematics learning. One teacher commented:

If we have done anything, I think the most exciting is to see more awareness [in the parents] of math all around. If that is something we did, I think it was to at least open their eyes to see that there was math everywhere and that they can use it. You know, by being in the car and playing a simple game of counting cars. Just opening their eyes to that.

Several teachers also reported that a number of parents were more comfortable visiting their child's classroom in the weeks during and after the intervention.

Now parents visit the classroom and hang out longer than they used to.

Nearly all teachers who participated as facilitators reported they would participate again, should the opportunity arise. Several mentioned they felt that by supporting families, they were helping their children learn and be better prepared academically.

Families Responded Positively to Elements of the Intervention

Analysis of the focus group transcripts indicates that intervention parents particularly appreciated three elements of the intervention: its daily routine, its high-quality content, and the transmedia aspects of the intervention.

Daily Routine

In focus groups, more than two thirds of parents frequently mentioned they liked the way the intervention was structured, with scheduled time each day to engage in learning interactions with their children. Parents reported that their child often reminded them when it was time to work together each day, which parents appreciated.

> *[Before the program,] I don't think we were doing it [supporting math] as much as we were supposed to. So it [the intervention] helped me do it every day. It was a little reminder. And she would remind me sometimes. 'Study Time' is what she calls it. She would grab the bag and bring it to where I was, and I'd say, 'Okay, let's do it.'*
>
> *He says, 'Daddy, Daddy, let's do the activity,' and he was very interested, and he would sit down with me. It's different when you share the education with your child than when you leave them alone. They want to share with us, and they feel proud to be sitting with us playing.*
>
> *It was nice to get that bonding time, to work with my kid one-on-one, and figure out ways to get him to work with me.*
>
> *It [the intervention] gave us the chance to put other things aside and sit down with our child.*

High-Quality Content

More than two thirds of parents mentioned they appreciated the high quality of the PBS KIDS content they used during the intervention. Parents mentioned appreciating all types of content: the digital games, hands-on activities, videos, and books. They found the content to be engaging, educational, and well designed.

> *I guess my favorite part was Curious George. We just love that little guy. I liked watching him play all the Curious George games, because I could just see his little smile. And he picks the books out. We have a little bookshelf so he'll pick the books he likes to read. He usually gets The Hungry Caterpillar [and we read it].*
>
> *The hands-on activities…were [our] favorite activities. I loved spending time with her, and she was very engaged in that, especially the hands-on.*
>
> *She liked the games, reading the books, the videos, hands-on activity, like the shapes that we brought home last time. Or whatever it was. She pretty much liked it all, and I did too!*
>
> *I liked when the games were done, with 'Good Job,' or you got another sticker. He would really like that. He would start clapping. I liked that he did learn so much from them, that he learned the numbers.*
>
> *She learned to count better with a game, which went up to number 20. Definitely, the game was really very good.*

She liked the videos a lot. All the videos that they put on, they watched all of them and they repeated them.

He loves the videos, like the counting videos. There's one that counts like to 1 to 20, like on the very first week. He loved that one.

Transmedia

A large majority of parents also said they appreciated the transmedia aspects of the intervention. They mentioned that the transmedia nature of the PBS KIDS educational content was powerful and allowed their children to learn mathematics content in different ways. Many parents in the focus groups mentioned they appreciated that mathematics concepts were represented in many modalities (digital games, hands-on activities, videos, and books). They liked having access to different tools to support children's different learning styles.

The program provides different tools. If the child doesn't learn with one of the tools, he can learn with another one. If you have the cards and that doesn't work, then you go to the computer and they teach them with figures, so sometimes the child gets more involved with that. Maybe another child prefers the cards.

This is the first time I became acquainted with this program. I like it because it really helps a lot, because it teaches children in a visual way, you have to watch and do things, so that was a great help for him.

This program is based on visualization so it's easier for the kids to learn because they are watching things and they are practicing. The visual aspect is very important, not so much because they play with the computer, but because they are watching and comparing things. As [another study participant] said, regarding adding and subtracting, it's very easy when they use the games to learn. They also learn the names of the things they are studying, as well as math.

I think everybody is a little different. We have a few parents that were missing [from the focus group], but [I remember] they really enjoyed the hands-on [activities]. They were excited about that. Then like for my son, it was more the computer. I guess it varies a little bit per child.

Parents also mentioned that the transmedia storytelling narratives, along with content delivered across multiple platforms, motivated their children to learn.

I think he's just going from [knowing] nothing, to learning so much. At first, he didn't like numbers. He didn't like to count numbers. I would try to count with him, but he didn't like it. I think just having something digital like a cartoon, like the games and the videos, made him more excited to learn. It encouraged him more to learn.

He loved the train game. Before, I would talk to him about math, but it didn't really quite stick. But doing the pre-game stuff [hands-on activities], and then the train game, like the caboose and stuff, that really helped him visualize, like if we do this many, and this many, you get more. He liked doing the handprints too, so it was a more effective way to teach him how to do stuff.

Summary of Key Findings

This study was designed to test the effectiveness of a school-based family engagement model in increasing preschoolers' knowledge and skills in mathematics, and in increasing parents' awareness of and ability to support their children's mathematics learning in the home environment. Additionally, the study focused on the feasibility of having teachers from participating schools facilitate parent meetings related to the intervention. Further, the study examined the relationship of socioeconomic status to learning outcomes and explored how key aspects of the model affect family engagement and learning.

The results indicate that children who participated in the intervention with their parents outscored their comparison group peers on the TEMA-3 by about three problems, with an effect size of 0.22. This difference was significant at the 0.05 level. TEMA-3 is a widely used, standardized, nationally normed achievement test. It measures children's numerical sense, which is the primary focus of the intervention. Children's mathematics ability was also assessed using a researcher-developed assessment focused on the concept of shapes. The intervention group had significantly lower scores on the baseline researcher-developed assessment of shapes. After the intervention, the intervention group's mathematics scores related to shapes scores grew significantly and were no longer inferior to those of the comparison group as measured by the post-assessment of shapes.

The results also indicate that parents were highly involved in supporting their children's mathematics learning at home. Many parents expressed surprise that their children could learn a diverse set of mathematics skills at the preschool age. They appreciated the intervention opportunity, which re-familiarized them with mathematics concepts and increased their awareness of the mathematics concepts their children were learning at home and at school. The results also indicate that parents increased their use of activities and strategies to support their children's mathematics learning at home and outside the home. Parents reported more frequent inclusion of mathematics dialogue and activities throughout the day, setting aside time each day to focus on learning, and using new strategies to support their children during learning activities.

The current study also highlights the potential for preschool teachers to facilitate mathematics content-based parent meetings. The results indicate that teachers were very effective in their roles as parent meeting facilitators. Not only did teachers deliver intervention activities with fidelity, they provided parents with a deeper connection to the preschool. Teachers reported they enjoyed the experience of teaching parents. In particular, they enjoyed seeing parents grow in their awareness of and ability to support their children's mathematics learning.

In regard to socioeconomic status, results indicate that mathematics ability increased in intervention group children at all income levels. A descriptive analysis of the intervention group TEMA-3 data indicates that children in low-income families, *and* those not identified as from low-income families, grew on average more than six points on the TEMA-3 mathematics assessment. Of particular importance, however, is that the mathematics ability of children from low-income families rose significantly during the intervention, which moves these children closer to meeting or surpassing important benchmarks such as those for school readiness, or standards for kindergarten. In the current effort to close the achievement gap and help all children reach academic benchmarks and standards to be successful in college and career, the intervention appears to support children from all income groups toward meeting important standards for kindergarten readiness and school success.

Conclusion

The current study builds on an intervention model developed and tested over the past several years. In summer 2012 and spring 2013, researchers at WestEd developed a family engagement model and conducted two pilot studies focusing on preschool families' involvement with PBS KIDS transmedia mathematics resources (McCarthy et al., 2012; McCarthy et al., 2013). In summer 2012, WestEd researchers supported participating families in learning mathematics by organizing the PBS KIDS transmedia suites and support materials, facilitating weekly parent meetings, and offering technical assistance. In spring 2013, WestEd trained Head Start preschool staff to act as program facilitators. The preschool staff helped lead parent meetings, with WestEd taking on the majority of the facilitation responsibilities. Both studies indicated the promise of using PBS KIDS transmedia suites in improving children's mathematics learning and their parents' awareness and support of their children's mathematics learning. Building on the success of the summer 2012 and spring 2013 intervention studies, a critical addition to this year's study was to include families from low-income and middle-income communities and to train participating preschool teachers to fully facilitate intervention parent meetings. Similar positive results were obtained from this year's study, indicating the strength of the intervention model and the potential effectiveness of having teachers facilitate the intervention's parent meetings.

In addition, it was found that participating children grew significantly on a rigorous assessment of mathematics achievement. These results point to the promise of the intervention in boosting low-income students' mathematics competencies and their readiness for kindergarten. As mentioned earlier, it has been suggested that economically disadvantaged preschool children have less extensive mathematics knowledge than their middle-income peers (Ginsburg & Russell, 1981; Hughes, 1986; Jordan, Huttenlocher, & Levine, 1994; Starkey & Klein, 1992; Starkey et al., 2004) and that early mathematics ability is a strong predictor of later mathematics achievement and overall academic success (Burchinal et al., 2011; Duncan et al., 2007; Jordan et al., 2009). The current intervention, if scaled up to reach more low-income preschool families, could have a profound effect on kindergarten readiness in children in low-income communities and perhaps affect children's future academic careers. Using a metaphor related to all boats rising on a high tide, the "rising tide" effect of this intervention allows for children at all income levels to "rise" in their mathematics ability and, most importantly, allows children in low-income families to "rise" toward meeting important standards for kindergarten readiness.

Overall, the study's findings suggest that the intervention model, using a family engagement learning experience that includes PBS KIDS transmedia content, is effective in supporting families and contributing to growth in preschool children's mathematics competencies

and can be scaled to reach a broader preschool audience. Families taking part in the intervention appreciated the community-based environment, with daily activities and playful, easy-to-access mathematics content. In addition, the PBS KIDS transmedia content appears to have contributed to the success of the intervention. Parents and children enjoyed the engaging games, videos, and hands-on activities. Parents mentioned that the well-designed PBS KIDS transmedia content helped their children learn mathematics. They appreciated that their children could learn and practice concepts in various modalities, whether it involved playing a counting game using cards with a family member, or playing a digital game that supports children as they learn to count to higher and higher levels. Parents also appreciated the quality of the PBS KIDS transmedia content, frequently mentioning that they could see that the content was well designed to support learning in an engaging format. The results of the study also indicate that the current model is promising for boosting young children's mathematics knowledge and skills. This site-based transmedia family engagement model helps parents provide mathematics support to their young children. Additionally, training teachers at preschool sites to deliver the curriculum appears to be feasible. These results suggest that broadly scaling up the intervention to additional preschool settings could prove effectual and cost-effective. CPB and PBS plan to make the materials used in the study available in 2016 to public media stations, educators, and other interested organizations. Titled the *WestEd/PBS KIDS Family Engagement Program*, the materials will be available on the PBS website.

It is recommended that additional research on the current transmedia parent engagement model be conducted. The positive results of the current research study, along with results from the two earlier studies of the model (McCarthy et al., 2012; McCarthy et al., 2013), suggest that the model is effective and should continue to be scaled up and tested. A randomized control trial of the model would be needed to provide strong evidence of the model's efficacy. In addition, longitudinal research including past and future study participants would provide information on the long-term effects of the intervention on student, parent, teacher, preschool, and community outcomes.

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Appendix A. Sample Weekly Parent Curriculum

Week 4 –Adding.

Goal: To find the sum of two groups of objects by counting.

Day 1 Activity
Train Station worksheet

Day 2 Activity and Online Game
Hands-on activity: Do You See My Seahorse? worksheet
Online Game: Do You See My Seahorse?

Day 3 Online Games
Online Games: Vegetable Harvest, Museum of Tens, Do You See My Seahorse?

Day 4 Free Play Games
Online Games: Train Station, Star Swiper, Vegetable Patterns, Vegetable Harvest, Museum of Tens, Do You See My Seahorse?

Videos
Curious George Bunny Hunt
Peg + Cat Counting Chickens

Appendix B. Sample Weekly Fidelity Log

Child's Name: _____ Date: _____

Day 1 – Hands-on Activity

Did you do the hands-on activity with your child?	Yes ____	No ____			
If yes, circle about how long did your child do the hands-on activity.	5–10 minutes	11–15 minutes	16–20 minutes	21–25 minutes	More than 25 minutes

Day 2 – Pre-game Activity and Online Game

Did you do the pre-game activity with your child?	Yes ____	No ____			
If yes, circle about how long did your child do the pre-game activity.	5–10 minutes	11–15 minutes	16–20 minutes	21–25 minutes	More than 25 minutes
Did you play the online game with your child?	Yes ____	No ____			
If yes, circle about how long did your child play the online game.	5–10 minutes	11–15 minutes	16–20 minutes	21–25 minutes	More than 25 minutes

Day 3 – Three Online Games

Did you play the three online games with your child?	Yes ____	No ____			
If yes, circle about how long did your child play the three online games.	5–10 minutes	11–15 minutes	16–20 minutes	21–25 minutes	More than 25 minutes

Day 4 – Free Play Online Games

Did you play the free play online games with your child?	Yes ____	No ____			
If yes, circle about how long did your child play the free play online games.	5–10 minutes	11–15 minutes	16–20 minutes	21–25 minutes	More than 25 minutes

Appendix C. Typical Timeline for Parent Meeting Facilitation and Fidelity Reporting

	Time
Welcome and Agenda	5 mins
Small Group Parent Discussion	10 mins
Activities and Demonstrations: Introduction to the Weekly Mathematics Theme; Day 1 Hands-On Activities; Day 2 Hands-On Activities and Online Game; Day 3 Online Games; Day 4 Free Play	30 mins
Closure: Introduction to the Weekly Book; Wrap-up	5 mins

Fidelity of Implementation Results Around Facilitation of Parent Meetings

Overall, participating preschool teachers reported they "very closely" or "closely" followed the weekly meeting plan as presented in the facilitator guide. Based on the teacher logs, participating preschool staff implemented the Welcome and Agenda component at each of the parent meetings. Researchers noted the meeting facilitators readily used the PowerPoint presentation to review the agenda and goals of the meeting in both Spanish and English. According to the data from the teacher logs, facilitators consistently reported implementing the Small-Group Parent Discussion component of the meeting. Researchers noted several parent meetings where facilitators encouraged parents to share their experiences both in the small-group and whole-group formats. Facilitators reported they wanted to enhance the level of family engagement at the meetings beyond what was prescribed in the facilitator guide, and, as a result, they occasionally asked parents to present their experiences about the previous week's activities to all the parents at the meeting through whole-group discussion and posters including written highlights from their small-group discussion.

According to the data from teacher logs, meeting facilitators reported consistently implementing the Introduction to the Weekly Theme component with a high level of fidelity to the facilitator guide. Analyzing the researcher observations from each meeting, the findings suggest that only a portion of the meetings fully implemented the Introduction to the Weekly Mathematics component of the meeting. Some facilitators closely followed the suggested script in the facilitator guide, whereas some facilitators did not integrate the Math Skills Wheel explanation into their discussion of the weekly mathematics topic. Facilitators modified the introduction section to be more "straightforward" for their parents. Observation data show that in lieu of using the Math Skills Wheel, the facilitators conducted an extended whole-group discussion about the week's mathematics topic.

Analysis of the weekly teacher logs suggest the Day 1 Hands-On Activities and Day 2 Hands-On Activity and Online Game components were reported to have a high level of implementation fidelity with some instances of modifications. According to the observation findings, the meeting facilitators often tailored these components to better meet the needs of their parents and enhance engagement during the meeting. Researchers noted the additional activities and engagement techniques the facilitators utilized to modify the facilitation of this component. For example, preschool teachers would include supplementary hands-on activities and mathematics examples from their classroom curriculum. Facilitators would often dramatize a parent and child interaction using the week's hands-on materials and model how to ask children questions to improve the potential for learning during the activity. In addition, teachers would ask parents to volunteer to be part of the hands-on activity demonstration and encourage parents to predict answers or count along with the online game.

The findings as suggested by the weekly teacher logs indicate that the Day 3 Online Games and Day 4 Free Play components were implemented with a high level of fidelity with few instances of modifications. In contrast, researcher observation findings suggest the online games component of the parent meeting faced intermittent issues with accessing the online games during the meeting implementation. Commonly reported technology issues include online games did not load or were very slow to load. Facilitators also spent additional time translating the games that provided English-only instructions. Time restrictions also impacted the parents' exposure to the final component of the parent meeting, the Introduction to the Weekly Book. Teachers reported this component was most often not implemented or only briefly introduced due to time constraints.

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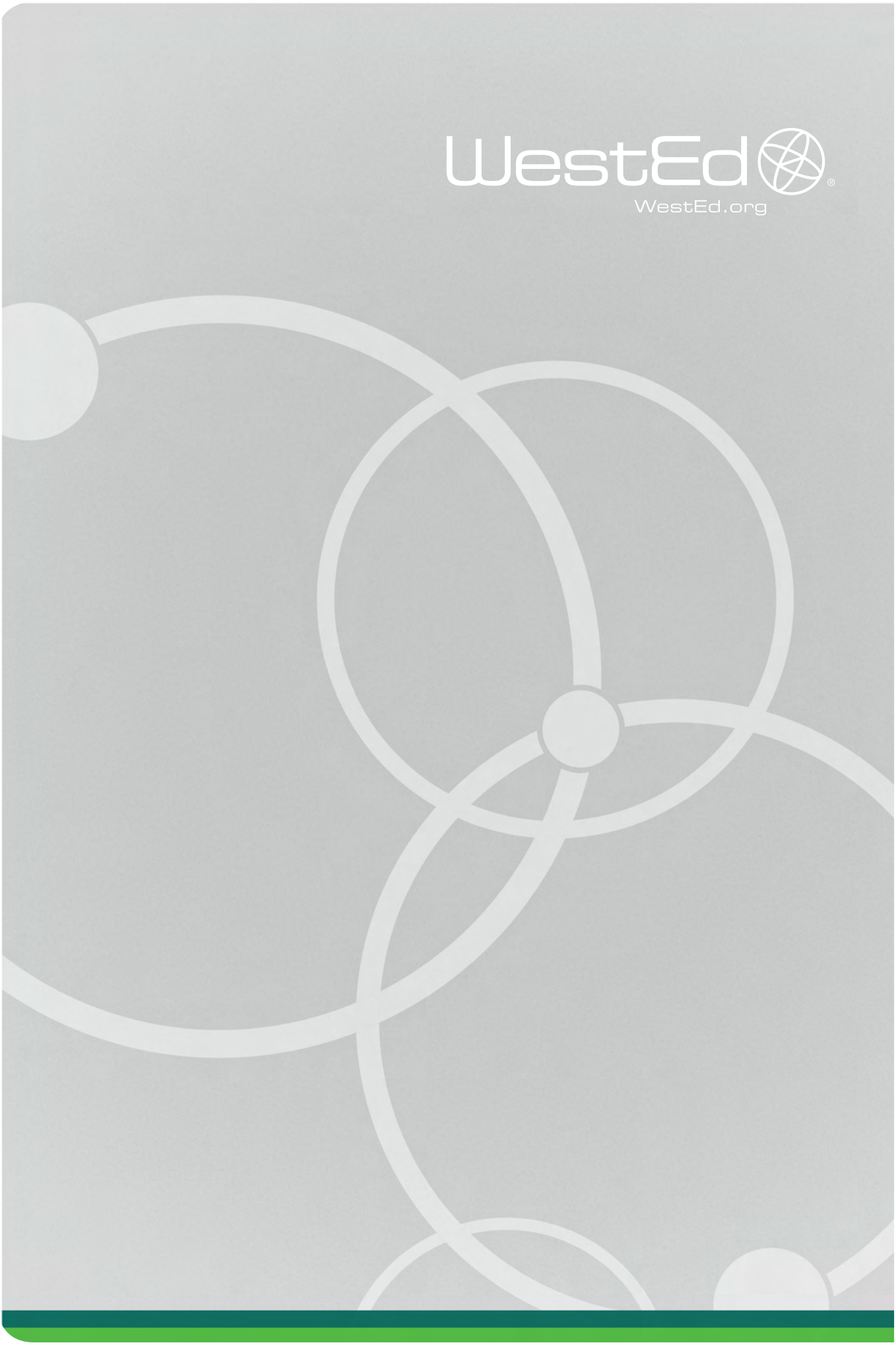
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