Title: Using Digital Media at Home to Promote Young Children's Mathematics Learning: Results of a Randomized Controlled Trial

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Background / Context:
Persistent inequalities in the academic learning trajectories of underserved students have led to a growing interest in interventions for young children who are at higher risk for academic difficulties later on. Since 2013, policy makers have worked to support children's formal educational experiences through state- and federal-level calls for universal preschool. However, many of these inequities begin before children reach formal learning environments. The U.S. public media system has dedicated substantial resources to understanding how it can improve conditions inside the place where children spend much of their time growing and learning: their homes. Families with young children spend considerable time engaging with media and technology resources at home (Rideout, 2014; Rideout, Vandewater, & Wartella, 2003), and children whose parents have less formal education tend to spend more time with TV and other screens than do their peers with more affluent, educated parents (Putnam, 2015). Young children spend more time viewing and playing with educational and non-commercial programming than do other groups (Rideout, 2013). The study presented here examines how educational public media, including videos and digital games designed for the home environment, can benefit young children's learning, focusing on children growing up in lower-income communities, who typically have limited exposure to experiences that are oriented toward school-readiness skills.

Public media has a long history of supporting early learning. Kearney & Levine (2015) recently explored impacts of home experiences with the most well-known public media intervention, Sesame Street. Results from the study indicated that children with access to Sesame Street were more likely to progress through school on track for their age. Research on more recent interventions suggests that engagement with public media in lab, school and home settings have been associated with gains in content domains like literacy, science, and math as well as problem solving, persistence, and other school readiness skills (Fisch, 2004, Penuel et al., 2012; McCarthy et al., 2012; Pasnik & Llorente, 2013).

Such public media resources often provide access to dynamic, multi-sensory representations of concepts, places, or people that otherwise would not be practical (or sometimes possible). Children can be intrinsically interested in and motivated by media and technology experiences, and this increased motivation is associated with deeper engagement and processing (Renninger, 2000). Media resources tend to represent essential concepts and content as integral to the advancement of narratives and story lines in ways that support attention and benefit learning (Fisch, 2004; Linebarger, Kosanic, Greenwood, & Doku, 2004). Similarly, children tend to form positive parasocial relationships with characters in media that can make them powerful resources for learning (e.g., Linebarger & Piotrowski, 2006; Richert, Robb, and Smith, 2011; Schiappa, Allen, and Gregg, 2007;). These characters can model learning behaviors like ways of thinking, talking, and cooperating (Troseth, Saylor, & Archer, 2006), and mathematical content knowledge (Gola, Richards, Lauricella, and Calvert, 2015). Some media resources, especially games, provide feedback to children and invite their active response, while other resources, like video, especially when mediated by an adult through Joint Engagement with Media (JEM), model and invite questioning, which can support engagement and learning. (Anderson et al., 2000; Crawley et al., 2002; Strouse, O'Doherty, and Troseth, 2013; Strouse and Troseth, 2013).

Purpose / Objective / Research Question / Focus of Study:

The study's primary goal was to understand how the integration of video, computer games and associated hands-on activities impacts children's mathematics learning. Specifically, the study sought to identify and describe (1) how children and families engaged with the selected

intervention resources in their homes, (2) how use of public media resources influenced children's knowledge of target mathematics and Approaches To Learning (ATL) skills; and (3) how use of these resources influenced parent/caregiver attitudes and beliefs.

Setting:

The study took place in homes in the New York City and San Francisco Bay areas. Researchers recruited children and families from local preschools serving children and families from low-income neighborhoods.

Population / Participants / Subjects:

The study sample included 197 4- and 5-year old children. These children attended 14 preschool centers in the New York metropolitan and San Francisco Bay areas, and were identified by their families as proficient in English. In addition a child's caregiver(s) needed to be proficient in English, Spanish, Mandarin or Cantonese to participate (see Table 1).

Intervention / Program / Practice:

The intervention centered on *PEG+CAT*, a PBS KIDS transmedia program, and was implemented over a 12-week period. The intervention was a designed series of 12 approximately 30-minute opportunities for children and their families to engage and interact with *PEG+CAT* episodes, video clips, online games, a tablet-based app, and print activities. Study materials allowed children and families to engage with the same characters, settings, and narratives on multiple devices. The time and intensity of each interaction was dependent on the child's interest and motivation, and the availability and motivation of parents. Each opportunity represented a chance for children to engage with mathematics and ATL skills, explore and deepen existing understandings of these skills, and/or refine emerging skills through application and practice, as often as possible in collaboration with a knowledgeable adult or sibling. Researchers selected and organized *PEG+CAT* resources that focused on patterns, geometry (2-D and 3-D shapes, spatial relationships), measurable attributes, ordinal numbers, and, the foundational skill of counting. The media also focused on ATL skills like flexible problem solving, persistence, and productive collaboration throughout its narrative. The intervention included a series of supports for parents, to provide modest guidance for engaging with study experiences on an ongoing basis, focusing on co-viewing media with children, engaging in and supporting children's use of math talk, and developing and supporting children's problem solving and persistence skills.

Research Design:

The study used a randomized controlled trial, two-condition design in which participating families were randomly assigned at the child level either to (1) a PBS KIDS treatment group or (2) a non-treated Business As Usual (BAU) comparison group. Families who were assigned to the PBS KIDS group were provided with technology resources (an Android tablet and a Chromebook laptop), a curated *PEG+CAT* experience, and supports for joint engagement. Participants in the BAU group were asked to continue with their typical home behaviors with regard to children's technology and media use.

Data Collection and Analysis:

A few standardized mathematics assessments have been found to reliably and accurately assess young children's mathematics learning (e.g., REMA, TEMA, EMAS), however they include a comprehensive list of mathematics skills in order to yield a indication of young children's overall mathematics ability. Lacking relevant subskill items, these available assessments were not well-suited to evaluate the PBS KIDS program given its focus on a smaller constellation of mathematics skills. Therefore, to assess children's mathematics outcomes, a team of assessment researchers developed and administered a set of assessment items aligned to

the skills addressed in the intervention, but not to the resources themselves, to avoid over-alignment and to ensure proper assessment of impact. The assessment was developed using guidelines for assessment design and was psychometrically evaluated using Item Response Theory (IRT) analyses. To assess children's ATL, the team administered the Preschool Learning Behavior Scale (PLBS; McDermott, Green, Francis, & Stott, 2000), a validated teacher measure of young children's classroom learning behaviors that was developed in partnership with preschool teachers for use in low-income samples. In addition, the research team developed and administered the Math Concepts and Problem Solving checklist (MCPS), a short teacher measure of children's understanding of the intervention's focal skills as well as their ability to apply mathematical skills in their everyday life and when solving problems.

Parents completed surveys before and after the study that focused on: (1) media and technology use at home, informal support for early mathematics by parents, and (3) children's problem solving and persistence behaviors at home. In order to track participant's access to the *PEG+CAT* content during the study, researchers configured the study's website and third-party applications installed on devices to log participant usage and engagement with the media and technology resources. Parents also completed weekly media diaries designed to capture daily and weekly use and interactions around media.

In addition, a subset of families were visited in their homes twice for researchers to directly observe when and for what purposes children and their families accessed media content, the social arrangements in which media was used, and obstacles or supports encountered when children and their families engaged with these media. Finally, a subset of caregivers participated in focused groups to gather information that contextualized and helped with the interpretation of parent survey data.

To examine the impact of the intervention on children's mathematics learning, the research team conducted a series of multilevel models using the Stata software environment (Version 13) and the mixed command using full maximum likelihood estimation. Even though randomization occurred at the child-level, multilevel analyses were fit to account for the nested structure of the data (children nested in classrooms and classrooms nested in centers) because children were recruited from and were enrolled in preschools during the duration of the study. To examine the potential moderation by pretest scores, researchers entered a moderator term (pretest x condition) into the model, at the child level. Findings from this model were examined to determine whether children with lower or higher pretest scores were more likely to benefit from the intervention. Analyses also incorporated parent survey and system log data as covariates in the models, including demographic characteristics and engagement with study resources. To examine the promise of the intervention in promoting adaptive ATL, researchers conducted multilevel models using PLBS data and followed the same process as for the child assessment data. Teacher data about children's mathematics learning, gathered via the Math Concepts and Problem Solving scale was examined at the item level by conducting two-sample Wilcoxon rank-sum/Mann-Whitney tests.

Findings / Results:

Children who participated in the intervention exhibited improvements in ordinal numbers, spatial relationships, and 3-D shapes compared to children in the BAU condition (ES=0.51, $p<.05$; see Table 3). No differences were found in teacher ratings of ATL or math concepts and problem solving between the two groups ($p>.05$). Parents and caregivers in the intervention condition reported a higher frequency of joint parent-child technology use (PBS KIDS: 94%; BAU: 80%; $p<.05$), more joint gameplay (PBS KIDS: 79%; BAU: 54%; $p<.05$, and more

conversation connecting digital media and daily life than did BAU caregivers (PBS KIDS: 93%; BAU: 67%; $p<.05$). These caregivers also reported significant increases in their confidence to support math learning for their children, as compared to BAU caregivers (PBS KIDS: 96%; BAU: 81%; $p<.05$), as well as in their agreement that technology and media were tools for math learning (PBS KIDS: 51%; BAU: 28%; $p<.05$). Furthermore, a higher proportion of intervention parents reported engaging in problem-solving strategies with their children at the close of the study than did BAU parents (PBS KIDS: 83%; BAU: 69%; $p<.05$). Finally, patterns of family engagement with the resources indicated the study resources were frequently accessed throughout the 12-week study period and intervention children were typically exposed to all target mathematical skills. However, the majority of families diverged from the suggested sequence, and overall use of the resources steadily declined over the course of the study (see Figure 1).

Conclusions:

This study documented how engagement with public media resources had measurable positive effects for children and their caregivers living in underserved communities. The study examined how a curated set of *PEG+CAT* videos, video clips, and digital games were taken up by families in home environments, and how the use of these media supported both positive mathematics learning outcomes in children and positive attitudes towards technology, mathematics learning, and technology as a tool for promoting mathematics learning in parents/caregivers. Findings from this study will be of particular interest to parents, educators, media producers, researchers, policy makers, and decision makers at funding agencies that focus on early learning and on the development of resources for parents and caregivers to support children's learning at home.

This study builds on research documenting the extent to which media and technology, including educational media, are now a regular part of American childhood (Rideout, 2013; Rideout, 2014). It also extends the work of researchers who are creating an evidence base emphasizing how home use of educational media can support children's learning of skills and practices that are valued in school (McCarthy et al., 2012; Starkey, Klein, & Wakeley, 2004). While efforts to improve formal early learning environments (e.g., adopting new curricula, using new resources, expanding teacher preparation and professional development) are essential, results from this study and others (Starkey, Klein, & Wakeley, 2004) suggest supported engagements between parents/caregivers and children show promise. While the majority of American preschool-aged children do not yet have access to high quality early childhood programs where they might learn the skills they need to succeed in school, public media programs are available to nearly all children. This disparity raises many pressing questions, and the one taken up by the public media system is this: Can children living in low-income communities be reached through public digital media? If so, can public media resources foster the learning of early mathematical skills likely to improve children's learning experiences and outcomes in kindergarten and beyond? The findings from the current study offer some evidence addressing these questions. More importantly, they open the door to future studies that continue to push the boundaries of how and when such learning can take place for all children, and particularly for children in families with limited financial resources, who might also be underserved by public preschools.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

Table 1. Descriptive statistics by condition

	Demographic Information	Treatment	BAU
		%	%
Maternal Education	Less than HS Diploma/GED	31.68	34.38
	HS Diploma/GED	28.71	30.21
	More than HS Diploma	37.62	33.33
Paternal Education	Less than HS Diploma/GED	35.64	38.54
	HS Diploma/GED	28.71	28.13
	More than HS Diploma	24.75	19.79
Total Household Income (2013)	Less than $25,000	52.00	51.58
	$25,000-$49,000	40.00	32.63
	$50,000-$74,000	3.00	6.32
	$100,000 or more	1.00	1.05
IEP or 504 Plan	Yes	5.94	2.08
	No	60.40	71.88
Number of Languages at Home	1	42.57	51.04
	2	54.46	47.92
	3	1.98	0.00
Languages	English Only	23.76	18.75
	Spanish Only	9.90	14.58
	Chinese Only	7.92	12.50
	Other Only	.99	6.25
	English and Spanish	49.50	41.67
	English and Chinese	3.96	2.08
	English and Other	.99	3.13
	Chinese and Other	0	1.04
Race/Ethnicity	Non-Hispanic White/Caucasian	1.98	2.08
	Hispanic/Latino	58.42	55.21
	Black/African American	14.85	10.42
	Asian	17.82	19.79
	Other	0.00	2.08
	Multiple	5.94	8.33
Child Gender	Male	53.47	46.88
	Female	45.54	53.13

Table 2. Study Data Sources

	Number of participants	Number of times administered/ reported	Timepoint administered/ reported
Outcome data			
Child assessment of target mathematic skills	Pre: 228 children Post: 190 children	2	Week 1 Week 12
Teacher rating scales • Preschool Learning Behavior Scale • Math Concepts and Problem Solving checklist	Pre: 234 children Post: 188 children Pre: 233 children Post: 188 children	2	Week 1 Week 12
Parent surveys	Pre: 196 parents Post: 188 parents	2	Week 1 Week 12
Engagement data			
Parent/caregiver media diaries	201 families	12	Weekly for 12 weeks
Home visits	20 families (10 PBS KIDS and 10 business as usual families)	2	Weeks 4–6 and Weeks 8–10
Parent/caregiver focus groups	20 parents/caregivers, across both PBS KIDS and business as usual families	1	Week 12
System log data • Google analytics • Tablet App tracker	100 PBS KIDS families 96 PBS KIDS families	2	Across study period

Table 3. Summary of PBS KIDS impact estimates

Impact Contrast	*n*	Coefficient	Hedges g (Effect Size)	Std. Error	*p*
Factor 1: Ordinal Numbers, Spatial relationships and 3D Shapes	172	5.26	0.51	1.12	0.000
Factor 2: Measurable Attributes and Pattern Creation	180	-1.02	-0.10	1.06	0.336
Factor 3: Counting, 2D Shapes and Pattern Continuation	182	-0.40	-.038	1.00	0.689

Figure 1. Percentage of Each Week's Specified Sequence and Cumulative Percent of Entire Sequence Viewed by PBS KIDS Families (*n*=100)