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Title: Preschool Teachers Can Use a PBS KIDS Transmedia Curriculum Supplement to Support Young Children's Mathematics Learning: Results of a Randomized Controlled Trial

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Background / Context
Early math achievement is a strong predictor of later school achievement, and this predictive power is even greater than that of early literacy achievement (Claessens, Duncan, & Engel, 2009; Duncan et al., 2007). Research suggests that all children are predisposed to use mathematical thinking (Balfanz, Ginsburg, & Greenes, 2003; Ginsburg, Choi, Lopez, Netley, & Chi, 1997), and recent studies show that young children's reasoning and knowledge in the areas of quantity, number, and spatial representation are malleable and sensitive to instruction (Claessens, Duncan, & Engel, 2009; Duncan et al., 2007). However, many existing methods of teaching early math are falling short for too many children—especially those from lower income households and English learners—and children who fall behind in math early on face long odds of catching up to their more mathematically proficient peers when it comes to high-school graduation rates, college readiness, and income as adults (Duncan, et. al., 2007; NAEYC & NCTM, 2010).

The National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) have called attention to the need for challenging and effective early childhood math programs (2012; 2010). Yet most preschool teachers are not trained in early math content, the development of young children's acquisition of math skills, or teaching strategies to promote math learning (Ginsburg, Lee, & Boyd, 2008), nor do they have access to high quality, comprehensive curricular content (Clements & Sarama, 2009).

The current study, a randomized controlled trial, explores how technology and educational transmedia resources can enhance prekindergarten math teaching and learning in preschools, especially those serving children who may be at risk for academic difficulties due to economic and social disadvantages. This research is part of a multi-year summative evaluation of the CPB-PBS Ready To Learn initiative, funded by the US Department of Education. A core aim of the initiative is delivering early math (and literacy) resources on new and emerging digital platforms such as tablet computers, interactive whiteboards, and smartphones, as well as better-established technologies such as computers, video displays, and gaming consoles, and to create learning experiences that leverage the unique capabilities of these various technology platforms.

Purpose / Objective / Research Question / Focus of Study
The study's goal was to understand how the integration of video, computer games and activities might impact children's mathematics learning. The study also examined whether the experience enhanced teachers' beliefs about their own understanding of math and the potential of technology-enhanced early math instruction. The following research questions guided the study: (1) *What is the impact of the PBS KIDS Transmedia Math Supplement and Technology & Media experience on young children's math learning and self-regulation?* (2) *What is the impact of the PBS KIDS Transmedia Math Supplement and Technology & Media experience on teachers' attitudes and beliefs about early math education, and using technology and media to support math learning?*

Setting:
The study took place in early childhood education centers primarily serving children from low-income households in the New York City and San Francisco Bay areas. To be eligible to participate in the study, instruction had to occur in English, and there had to be at least 10 four- to five-year-olds enrolled who were proficient in English. Teachers also had to be willing to

participate in professional development in math instruction and technology integration, and be willing to use new classroom technology.

Population / Participants / Subjects:
The study examined four- and five-year-old children from low-income households and their teachers. The final sample consisted of 85 classrooms (40 in New York City and 45 in San Francisco). Descriptive information for the children is available in Table 1. While all children in participating classrooms were invited to engage in study activities, researchers randomly selected a sample of approximately 10 children from each classroom to participate in assessments.

A sample of 157 teachers in New York City and San Francisco participated in the study. The sample, which included lead teachers, teacher assistants, and aides, comprised an ethnically diverse group and more than half of teachers (54%) reported earning a bachelor's degree or higher. On average, teachers reported approximately 13 years (SD=9.1) of teaching experience. There were no significant differences between the teachers in the three conditions.

Intervention / Program / Practice:
The PBS KIDS Transmedia Math Supplement was centered around PBS KIDS videos and digital games, played on a select set of learning technologies (i.e., preschool-specific interactive whiteboards and laptop computers). The Supplement used a transmedia approach, focusing on familiar characters, settings, and narratives across different media formats, such as digital video and interactive online games. The supplement also included non-digital materials, like books and foam shapes, and was designed to complement existing instructional routines like circle time and free play centers.

The research team developed the Supplement by drawing on existing research of early childhood math instruction and sequencing (Clements & Sarama, 2009; Ginsburg, Greenes, & Balfanz, 2003), the team's understanding of typical early childhood math instruction from the 2011 Context Study (EDC & SRI, 2011) and 2012 Prekindergarten Transmedia Math Pilot Study (EDC & SRI, 2012), and existing research on successful technology integration in early childhood classrooms (McManis & Gunnewig, 2012). The target math skills included: counting, subitizing, recognizing numerals; recognizing, composing, and representing shapes; and patterns.

Research Design:
The study used a randomized controlled trial, three-condition design:

- PBS KIDS Transmedia Math Supplement: A third of classrooms (26) received the Math Supplement described above as well as the interactive whiteboards, laptop computers, broadband Internet access, technical support, and training and coaching required to enact the Supplement. Teachers also received pre-study training and ongoing coaching support.
- Technology & Media: A third of classrooms (30) received the same technology, technical support, and access to coaches as the Math Supplement teachers, but did not receive the structured curriculum for integrating these resources into their instruction.
- Business as Usual: A third of classrooms (29) were instructed to continue with their typical instructional routines and did not receive any technology or supports. They did not receive new technology to augment what might have been present before, and did not receive professional development or coaching during the study.

Data Collection and Analysis:
Trained assessors conducted pre/post individual assessments using three assessments. The research team randomly assigned assessment order to avoid unintended order effects. For a fuller description of these measures, see Pasnik & Llorente (2013).

The *Research Based Early Mathematics Assessment* (REMA short form) (Weiland et al., 2012) served as a valid and reliable standardized assessment of children's math skills. The 19 items in the REMA short version assess math skills considered essential in preschool and kindergarten (NGA/CCSSO, 2010; Clements & Sarama, 2009)—recognition of number and subitizing, and shape composition, and patterning (Weiland et al., 2012). Each item includes a game-like activity that involves the assessor reading a verbal prompt and, at times, demonstrating with manipulatives. Children provide a verbal response, point, or engage with manipulatives.

The *Supplement-based Assessment* (SBA) was developed by the research team to assess children's understanding of the concepts in the PBS KIDS Transmedia Math Supplement. The SBA contains 20 items and targets children's understanding of counting; number recognition and subitizing; shapes; and patterns. As in the REMA, SBA items involved game-like activities that required assessors to read a verbal prompt and children to provide a verbal response, point, or engage with manipulatives. Early childhood researchers with assessment experience developed the SBA and pilot-tested them on a sample of preschool children and revised as necessary.

The *Head-Toes-Knees-Shoulders* (HTKS) measure (Ponitz et al., 2008) is a validated measure of young children's behavioral self-regulation.

Findings / Results:
As measured by the SBA assessment, children in the PBS KIDS Transmedia Math Supplement condition learned significantly more mathematics than children in both the Technology & Media and Business as Usual conditions. Children in the PBS KIDS Transmedia Math Supplement condition exhibited significantly higher SBA scores than children in the Technology & Media condition (1.43 points, effect size of 0.22, $p<.001$). This means that being in the Math Supplement condition would lead to a 9% increase in percentile rank for an average student in the Technology & Media group. A marginally significant effect also was detected in REMA data. Children in the Math Supplement condition exhibited higher REMA scores than children in the Technology & Media condition (1.09 points, effect size of .15 and $p < .06$). Furthermore, children in the PBS KIDS Transmedia Math Supplement condition exhibited significantly higher SBA scores than children in the Business As Usual condition (1.51 points, effect size of 0.24, $p <.001$). A marginally significant effect also was detected using the REMA, such that children in the PBS KIDS Transmedia Math Supplement condition exhibited higher REMA scores than children in the Business as Usual condition (1.09 points, effect size of .15 and $p < .07$).

No significant effects were detected for Head-Toes- Knees-Shoulders scores. A summary table of the main effects model appears in the appendix.

Preschool teachers who enacted the PBS KIDS Transmedia Math Supplement reported significant changes in their confidence and comfort with early math concepts and teaching with technology. See table 4 for the proportion of teachers who reported teaching math concepts with

technology. There was a significantly greater increase in the proportion of teachers who reported teaching shapes, numeracy, and patterns in the PBS KIDS Transmedia Math Supplement condition compared to teachers in the Technology & Media condition. For more details on the teacher outcomes, see Pasnik & Llorente (2013).

Conclusions:
These positive findings—children learning significantly more math and teachers expressing greater comfort with technology and confidence in their math teaching as a result of implementing the Math Supplement—support the notion that the thoughtful integration of well-designed digital resources coupled with adequate teacher supports can positively influence child and teacher outcomes.

The sharp, cohesive curricular focus of the Supplement stands in contrast to a common approach of technology integration, which tends to leave teachers to select resources piecemeal and on their own. The study results provide further evidence of the weakness of such an approach. Not only did learning gains not appear in the Technology & Media condition, but teachers in this condition reported spending less time on math instruction than the Business As Usual condition, suggesting that the difficult work of integrating technology actually interrupted or interfered with typical instructional routines.

Conversely, when teachers are prepared with the content knowledge and pedagogical experience needed to mediate children's learning with technology, children are able to make use of the learning opportunities available through engagement with digital media. Digital transmedia's potential to advance content-area learning for young children may be of greatest value for those children who are most in need of academic support. In other words, "The children who have the most to gain are the ones who gain the most." Finally, the results demonstrate that recognizing teachers as the professionals they are is both a starting place and a commitment that must be sustained.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

Table 1. Total sample of children and descriptive statistics for age by condition.

Condition	Number of Children	Mean Age	SD
Overall	966	4.55	0.33
PBS KIDS Transmedia Math Supplement	307	4.55	0.34
Technology & Media	321	4.55	0.33
Business as Usual	338	4.56	0.33

Table 2. Implementation Data Collections Activities

Condition Components	PBS Transmedia Math Supplement	Technology & Media	Business as Usual
Interactive Whiteboard, 3 Chromebook laptops, Wireless Internet	✓	✓	
Printed 10-week PBS KIDS Transmedia Math Supplement Guide with sequenced activities	✓		
Printed 10-week guide with pointers to transmedia resources on PBS KIDS Lab and PBS KIDS websites		✓	
Professional development for teachers on math and use of technology	✓	✓	
Professional development for teachers on use of the PBS KIDS Transmedia Math Supplement	✓		
Professional development on math after study implementation			✓
Hands-on materials to enact 10-week PBS KIDS Transmedia Math Supplement guide	✓		
Website supporting guided transmedia experience with all videos and games in sequence	✓		
Ongoing technology support	✓	✓	
Ongoing onsite coaching to support technology integration	✓	✓	
Ongoing onsite coaching to support use of the PBS KIDS	✓		

Table 3. Summary of PBS KIDS Transmedia Math Supplement impact estimates

Impact Contrast	Coefficient	Std. Error	Hedges' g (Effect size)	p	Multiple Comparison Test*
SBA					
(1)PBS KIDS Transmedia Math Supplement vs Business as Usual	1.51	0.302	0.24	<0.001	significant
(2) Technology & Media vs Business as Usual	0.08	0.309	0.01	0.789	---
(3) PBS KIDS Transmedia Math Supplement vs. Technology & Media	1.43	0.288	0.22	<0.001	significant
REMA					
(1)PBS KIDS Transmedia Math Supplement vs Business as Usual	1.09	0.589	0.15	0.064	---
(2) Technology & Media vs Business as Usual	0.00	0.587	0.00	0.996	---
(3) PBS KIDS Transmedia Math Supplement vs. Technology & Media	1.09	0.571	0.15	0.056	---
HTKS					
(1)PBS KIDS Transmedia Math Supplement vs Business as Usual	-0.02	1.432	0.00	0.991	---
(2) Technology & Media vs Business as Usual	-0.89	1.460	-0.05	0.542	---
3) PBS KIDS Transmedia Math Supplement vs. Technology & Media	0.87	1.370	0.05	0.524	---

Table 4. Proportion of teachers who reported teaching math concepts with technology

	Business as Usual		Technology & Media		PBS KIDS Transmedia Math Supplement	
	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey	Pre-Survey	Post-Survey
Counting	59%	56%	33%	84% **	51%	90% **
Subitizing	26%	28%	22%	54% *	16%	64% **
Identifying numerals	50%	50%	28%	90% †	47%	84% **
Shapes	50%	44%	24%	66% **	40%	84% **
Patterning	46%	46%	33%	80% **	49%	84% *
Addition	30%	34%	22%	78% **	33%	76% **
Subtraction	24%	24%	17%	62% **	27%	66% **
Measurement	15%	24%	20%	72% **	27%	60% *
Documenting/ analyzing results	17%	14%	4%	28%*	47%	34% *

*$p<.05$, ** $p<.001$, †Comparing PBS Transmedia Math Supplement to the Technology & Media Condition.