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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Summative Evaluation of the
CPB-PBS *Ready To Learn Initiative*

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Information on Who Conducted the Study

The collaborative *Ready To Learn* summative evaluation team includes researchers from two institutions: the Education Development Center's Center for Children and Technology and SRI International's Center for Technology in Learning.

Education Development Center, Inc. | Center for Children and Technology

The Center for Children and Technology (CCT) is a unit of Education Development Center, Inc., a nonprofit international research and development organization dedicated to improving the quality, effectiveness, and equity of education throughout the United States and in more than 35 countries. Since 1981, CCT has been at the forefront of creating and researching new ways to foster learning and to improve teaching through the development and thoughtful implementation of new educational technologies. CCT's work is centered in three areas: research, including basic, formative, and program evaluation; design and development of innovative technology prototypes and products; and the implementation and operation of large-scale technology integration efforts.

SRI International | Center for Technology in Learning

SRI International is an independent, nonprofit research institute conducting client-sponsored research and development for government agencies, commercial businesses, foundations, and other organizations. The mission of the Center for Technology in Learning (CTL) is to improve learning and teaching through innovation and inquiry. CTL research and development activities contribute to the knowledge base of effective learning and teaching and embody research insights in the innovative design, use, and assessment of interactive learning environments. In its development, research, and evaluation work, CTL seeks to create tools that lead to better teaching and learning, to develop assessments and conduct evaluations that contribute to the evidence base about the effectiveness and conditions for success of technology-supported innovations, and to inform both the policy and research communities.

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Study in Brief

This report presents results from the *Ready To Learn* Prekindergarten Transmedia Mathematics Study, a principal part of the summative evaluation of *Ready To Learn*, which is a partnership between the US Department of Education, the Corporation for Public Broadcasting, and PBS. Researchers found that preschool children who experienced a PBS KIDS Transmedia Math Supplement developed essential early mathematics skills. The PBS KIDS Transmedia Math Supplement was centered around public media videos and digital games, played on a selected set of learning technologies (interactive whiteboards and laptop computers). The important skills measured—counting; subitizing; recognizing numerals; recognizing, composing, and representing shapes; and patterning—increased significantly for the study's four- and five-year-old children, who were from traditionally economically disadvantaged communities where children are often less prepared for kindergarten than are their more socially and economically advantaged peers. Also important, preschool teachers who enacted the PBS KIDS Transmedia Math Supplement reported significant changes in their confidence and comfort with early mathematics concepts and teaching with technology.

Introduction

There is growing recognition of the importance of early mathematics learning, and increasing awareness of the tremendous potential all children have to develop a broad range of quantitative thinking skills. Early mathematics achievement is a strong predictor of later school achievement, and this predictive power is even greater than the predictive power of early literacy achievement (Claessens, Duncan, & Engel, 2009; Duncan et al., 2007). The National Association for the Education of Young Children (NAEYC) and the National Council of Teachers of Mathematics (NCTM) jointly have called attention to the need for appropriate, challenging, and effective early childhood mathematics programs (2002; 2010). Yet most preschool teachers are not trained in early mathematics content, the developmental trajectory of young children's acquisition of mathematics skills, or teaching strategies to promote mathematics learning (Ginsburg, Lee, & Boyd, 2008).

Despite the increased call to address mathematics in the preschool years, particularly with the introduction of the Common Core Standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), few early learning mathematics curricula have been developed that are comprehensive in their coverage of topics beyond number and operation and geometry (Clements & Sarama, 2009). Moreover, very few have undergone evaluations, particularly with low-income populations (Clements & Sarama, 2007) or using randomized controlled trials to test causal relationships between a specific curriculum and child outcomes (Clements & Sarama, 2002). Worse, many existing methods of teaching early mathematics are falling short for too many children—especially those from lower income households and English learners—and children who fall behind in mathematics early on face long odds of ever 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 current study, a randomized controlled trial, explores how technology and educational transmedia resources can enhance prekindergarten mathematics 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 the summative evaluation of *Ready To Learn*, a partnership between the US Department of Education, the Corporation for Public Broadcasting, and PBS, that seeks to develop engaging, high-quality educational programming and supports for two- to eight-year-old children living in low-income households. A core aim of the initiative is delivering early mathematics (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 for young children's learning. As the summative evaluation team for *Ready To Learn*, Education Development Center, Inc. (EDC) and SRI International (SRI), document and, whenever possible, measure the impact of transmedia mathematics resources on children's school readiness.

The study sought to test whether the experience of participating in a 10-week PBS KIDS Transmedia Math Supplement, which curates media-rich and non-media activities into a set curricular sequence, would support children's growth of target mathematics skills: counting; subitizing; recognizing numerals; recognizing, composing, and representing shapes; and patterning. The materials in the supplement were designed to provide more structured supports for teachers to successfully enact a full range of mathematics instruction, as well as a way to integrate this instruction into their current teaching strategies and practices—both those related to mathematics and in general. Because the PBS KIDS Transmedia Math Supplement provided onsite technical and instructional support, a developmentally appropriate and sequenced set of integrated activities that target early mathematics learning, and the digital tools required to implement them, the research team also examined whether the experience of enacting the curriculum supplement enhanced teachers' beliefs about their own understanding of mathematics and towards technology-enhanced early mathematics instruction.

Research Design

The main goal of the current study was to determine if and how a transmedia approach with PBS KIDS properties serving as cornerstones of a preschool mathematics curriculum supplement, helped children develop targeted early mathematics skills. For the purpose of this study, transmedia means the use of familiar characters, settings, and narrative themes or stories across different media formats, such as digital video, interactive online games, and interactive whiteboard applications. In pursuit of this goal, the *Ready To Learn* summative research team identified three categories of research questions.

Research Questions

Child Learning Outcomes

- What is the impact of the PBS KIDS Transmedia Math Supplement and Technology & Media experience on young children's mathematics learning?

- What is the impact of the PBS KIDS Transmedia Math Supplement and Technology & Media experience on young children's self-regulation?[1]

Teacher Outcomes

- What is the impact of the PBS KIDS Transmedia Math Supplement and Technology & Media experience on teachers' attitudes and beliefs about early mathematics education, and using technology and media to support mathematics learning?

1 The main impact question for the study focuses on mathematics learning (namely, target skills), but the research team also examined potential impacts on self-regulation (skills that may be indirectly promoted through activities) as an exploratory question.

Implementation

- To what extent do teachers in the PBS KIDS Transmedia Math Supplement group implement the curriculum supplement with fidelity?

- What are the successes and barriers, if any, that teachers in the PBS KIDS Transmedia Math Supplement group encounter while implementing the curriculum supplement?

Child and Teacher Sample

The research team recruited a sample of 92 classrooms (46 in New York City and 46 in the San Francisco Bay Area) from preschool agencies and centers serving three- to five-year-old children primarily from low-income households.

Screening and eligibility for recruitment into the study were based on the following requirements:

- Centers that predominantly served children from low-income households (e.g., Head Start centers that have income eligibility requirements or public preschool programs that serve children who are eligible for state subsidy/free or reduced price lunch).

- Classrooms where instruction occurred in English.

- Classrooms that had at least 10 four- to five-year-olds enrolled who were proficient in English (given that resources and assessments were available only in English).

- Participants were informed that there were three study conditions, as well as the process of random assignment to a particular condition. Based on this assignment, participants were willing to (1) use the PBS KIDS Transmedia Math Supplement; (2) receive training and coaching; (3) complete surveys; and (4) keep logs of their mathematics instruction.

- Participants were willing to participate in some form of professional development in mathematics instruction and technology integration, and were willing to use new classroom technology.

Upon completion of recruitment, the research team randomly assigned participating classrooms to one of three conditions: a PBS KIDS Transmedia Math Supplement condition, a Technology & Media condition, or a Business as Usual (BAU) condition.

The final sample of classrooms in the study consisted of 86 classrooms:[2]

- 26 PBS KIDS Transmedia Math Supplement classrooms (12 in New York City; 14 in the San Francisco Bay Area)
- 30 Technology & Media classrooms (15 in New York City; 15 in the San Francisco Bay Area)
- 29 Business as Usual classrooms (13 in New York City; 16 in the San Francisco Bay Area)

A sample of 157 teachers (84 in New York and 82 in the San Francisco Bay Area) participated in the study. The sample of teachers included lead teachers, teacher assistants, and aides. A total of 137 teachers completed a survey and provided demographic and background information prior to the study.

The teachers in the sample comprised a diverse group, reporting the following:

- 44% Hispanic, Latino, or Spanish origin
- 23% Black or African American
- 18% White
- 12% Chinese
- 7% Filipino
- 2% American Indian or Alaskan Native
- 2% Other Asian

More than half of the teachers (54%) reported having completed a bachelor's degree or higher (21.2% reported having completed a graduate or professional degree, 32.8% having completed a BA or BS); 24.1% reported having completed some college or technical school classes; 17.5% reported having completed an AA, AS, or technical degree; and 3.6% reported having completed a high school degree or GED. On average, teachers reported approximately 13 years (SD=9.1) of teaching experience in general, and 11 years (SD=8.3) of preschool teaching experience. There were no significant differences between the PBS KIDS Transmedia Math Supplement and Business as Usual teachers or between Technology & Media and Business as Usual teachers.

2 After randomization but before implementation, one classroom in the PBS KIDS Transmedia Math Supplement group withdrew from the study. Early during implementation, 13 classrooms on the East Coast were dropped from the study (5 PBS KIDS Transmedia Math Supplement, 3 Technology & Media group, and 5 BAU). The classrooms that were dropped moved some teachers to different classrooms, which resulted in potential cross-condition contamination. Because this happened at the start of the implementation period, the research team was able to recruit nine additional East Coast classrooms that were included in the study. This second cohort of classrooms was randomized to condition following the same procedure used for the original sample of classrooms. One of these nine additional classrooms dropped from the study before implementation began.

All children in participating classrooms were invited to participate in the study (engage in classroom activities). However, the research team randomly selected a sample of approximately 10 children from each participating classroom to participate in assessments of learning. Table 1 lists the total number of children in the overall sample and by condition, and provides descriptive information regarding children's ages.

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

Condition	N	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

The Study's Three Conditions

Researchers designed the study to include three conditions. In addition to the PBS KIDS Transmedia Math Supplement and Business as Usual groups, findings from the research team's 2012 Prekindergarten Transmedia Math Pilot Study convinced us to include the Technology & Media group. Because no study classroom had reliable Internet access or the learning technologies included in the study, it was appropriate to include a study condition that reflects teachers' typical experience with technology integration—receiving technology, and integrating it into their instructional routine, often with minimal training and support. (Table 3 provides an overview of the components of the three conditions and the next section describes the PBS KIDS Transmedia Math Supplement elements in greater detail. See Appendix A: Site Implementation Characteristics on page 50.)

PBS KIDS Transmedia Math Supplement

Teachers in the PBS KIDS Transmedia Math Supplement condition enacted the PBS KIDS Transmedia Math Supplementary curriculum, which included *Ready To Learn* videos and games available via public media broadcasting and online services, and also non-digital activities. They received preschool-specific interactive white boards and laptop computers, along with broadband Internet access required to connect these devices to the Internet, and on-demand technical support to ensure the technology functioned properly throughout the study period. Teachers also received pre-study training and ongoing coaching support focused on the enactment of the supplementary curriculum.

Technology & Media

Teachers in the Technology & Media condition were asked to use new technologies and transmedia materials to target the same mathematics skills as the PBS KIDS Transmedia Supplement condition. Technology & Media classrooms were equipped with the same technology resources, and teachers received the same level of technology support as those in the PBS KIDS Transmedia Math Supplement condition. Technology & Media condition teachers received pre-study training on technology and target mathematics skills, and ongoing coaching to support technology integration for mathematics learning. Researchers did not provide the curriculum supplement. Instead, teachers were encouraged to use the new technologies and given pointers to digital resources they might use to enrich their existing lessons.

Business as Usual

Teachers in the Business as Usual control condition continued to provide the same learning opportunities as before the study began. They were not informed about the target mathematics skills, and continued to use their existing curriculum frameworks, curricula, and learning materials. 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.

Schedule

Below is the 18-week schedule the research team followed during implementation of the current study in the spring of 2013. Table 2 outlines the installation, professional development, implementation, research, and data collection timelines for the three study conditions.

Table 2. Study implementation and data collection schedule by week

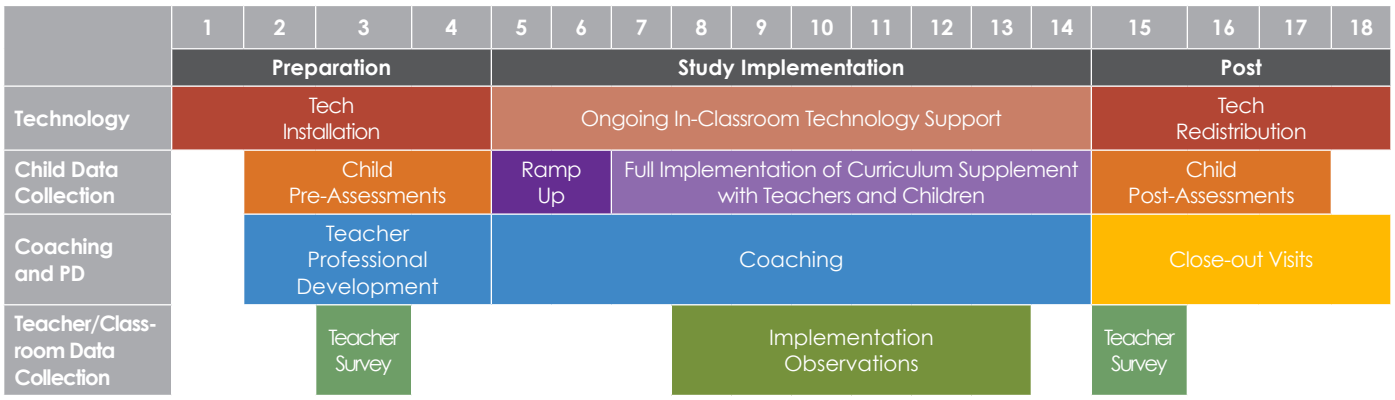

Table 3. Implementation Data Collection Activities

Condition Components	PBS KIDS 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 mathematics and use of technology	✓	✓	
Professional development for teachers on use of the PBS KIDS Transmedia Math Supplement	✓		
Professional development on mathematics 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 Transmedia Math Supplement	✓		

The PBS KIDS Transmedia Math Supplement

The 10-week PBS KIDS Transmedia Math Supplement that was the focus of the study was a sequence of curricular activities centered around early childhood mathematics practices, digital resources and technical support to aid technology integration into instruction, and ongoing teacher coaching and just-in-time professional development supports. The transmedia supplement was designed to capture children's interest and attention and to promote their mathematics learning, as well as support teachers' understanding of their classroom mathematics practice.

Specifically, the supplement targeted the following mathematics skills important to children's success:

- counting
- subitizing
- recognizing numerals
- recognizing, composing, and representing shapes
- patterning

Curricular Activities

The research team developed the PBS KIDS Transmedia Math Supplement from the ground up, drawing on existing research of appropriate early childhood mathematics instruction and sequencing (Clements & Sarama, 2009; Ginsburg, Greenes, & Balfanz, 2003), the team's understanding of typical mathematics instruction in early childhood classrooms from the 2011 Context Study (Education Development Center & SRI International, 2011) and 2012 Prekindergarten Transmedia Math Pilot Study (EDC & SRI, 2012),

and existing research on successful integration of technology into early childhood classrooms (McManis & Gunnewig, 2012). A central component of the PBS KIDS Transmedia Math Supplement was the transmedia approach to digital resources, namely activities centered on interactive games designed by public media producers as part of the CPB-PBS *Ready To Learn Initiative* and companion videos that include familiar characters, narratives, and environments that are interesting and attractive to children. The PBS KIDS Transmedia Math Supplement materials were designed to act as a framework for teachers as they engaged in the 10-week study experience.

In addition to the core digital assets, below are key features of the PBS KIDS Transmedia Math Supplement:

- Overarching theme: Being a "mathematics detective." Throughout the PBS KIDS Transmedia Math Supplement, children were encouraged to be "mathematics detectives" and sleuth out mathematics in a variety of videos, games, and activities.

- *Ready To Learn* transmedia assets. These included mathematics-focused videos and interactive games available on the PBS KIDS Lab website. See Appendix B: Digital Assets Included in the PBS KIDS Transmedia Math Supplement on page 51.

- Builds on common preschool activity formats. The PBS KIDS Transmedia Math Supplement included whole-group, small-group, paired, and individual activities. These groupings of instruction were based on the most common arrangements in current prekindergarten classrooms, each with its own affordances for teaching and learning.

- Structured experience. Researchers designed the PBS KIDS Transmedia Math Curriculum Supplement to be enacted over four days a week, for no more than 2.5 hours per week, over the course of 10 weeks.

- Teacher's Guide. Researchers provided teachers with printed guide containing the activities, suggested scripts, and suggestions for instruction for implementing the PBS KIDS Transmedia Math Supplement. The guide reviewed the preschool mathematics skills covered in the PBS KIDS Transmedia Math Supplement and provided the study plan from pre-assessment to ongoing implementation to post-assessment. The guide also contained tips for introducing technology to children; a review of the videos and games included in the PBS KIDS Transmedia Math Supplement; and the delivery, installation, and removal schedule for technology. See Appendix C: Teacher's Guide Included in the PBS KIDS Transmedia Math Supplement on page 52.

- Comprehensive materials. Teachers received all of the materials and digital assets they needed to enact the PBS KIDS Transmedia Math Supplement. Materials included both technology (interactive whiteboards and laptop computers) and manipulatives (such as dry-erase boards and markers, pattern cards, and game pieces). See Appendix D: Non Digital Materials Included in the PBS KIDS Transmedia Math Supplement on page 53 and Appendix E: Books Included in the PBS KIDS Transmedia Math Supplement on page 55.

Researchers provided teachers in the PBS KIDS Transmedia Math Supplement group with a recommended implementation schedule for a four-days-a-week implementation cycle as part of the Teacher's Guide. The schedule gave suggestions for when to introduce and complete various study activities. Although teachers were free to follow the schedule, they were encouraged to work with their coach to tailor a schedule that fit their classroom needs while integrating all study activities each week. (An example is shown in Table 4).

Table 4. Weekly sample schedule of the PBS KIDS Transmedia Math Supplement activities

Monday	Tuesday	Wednesday	Thursday
Video Co-Viewing (25 minutes)	Mathematics Detective Journal (20 minutes)	Mathematics Circle Routine (10 minutes)	Challenge Game Play (25 minutes)
	Easy Game Play (10 minutes)	Guided Reading (15 minutes)	
Computer Center (~10 minutes per pair of children)	Computer Center (~10 minutes per pair of children)	Computer Center (~10 minutes per pair of children)	Computer Center (~10 minutes per pair of children)
	Hands-On Centers (~10 minutes per pair of children)	Hands-On Centers (~10 minutes per pair of children)	Hands-On Centers (~10 minutes per pair of children)

Teachers in the Technology & Media condition received no supplementary curriculum. They were asked to build on their existing mathematics activities and content by integrating technology and media into their instruction. Researchers encouraged teachers to use the interactive whiteboard and laptop computers for digital content for approximately two hours each week to support mathematics instruction in the classroom and provided instructions for accessing online resources, but provided no formal requirements for content or in what manner to use the technology to support learning. Likewise, teachers were not given a specific set of mathematics skills to cover, but were encouraged to address the same skills emphasized in the PBS KIDS Transmedia Math Supplement condition, plus two additional skills that researchers felt PBS KIDS Lab games covered thoroughly: measurement, and documenting and analyzing data.

Teachers in this condition received a small Teacher's Guide that provided information about:

- The technology they received
- How to integrate technology into early learning settings as a support for instruction
- Internet safety precautions
- Key early learning mathematics skills

Technology Tools and Technical Supports

All PBS KIDS Transmedia Math Supplement and Technology & Media classrooms received the technology tools and technical support required to participate in the study. In addition to the resources listed below, the research team also ensured classrooms were equipped with broadband wireless Internet by tapping into existing center resources or, when necessary, setting up new networks with wireless routers or mobile broadband modems.

Teachers in the PBS KIDS Transmedia Math Supplement and Technology & Media conditions received:

- One interactive whiteboard with mini-pc and projector, situated on an interactive whiteboard cart specially designed at a low height for use with young children (For an image of the interactive whiteboard setup, see Appendix F: Images of Interactive Whiteboard and Laptops Included in the PBS KIDS Transmedia Math Supplement on page 56)
- A wireless keyboard with track pad mouse to control the interactive whiteboard
- Three Google Chromebook laptop computers with three wireless mice and six headphones for use by children in the laptop center-time area
- Headphone splitters to accommodate paired play at the laptops

To support use of the PBS KIDS Transmedia Math Supplement by teachers, the research team developed a study-specific website available only to this group of teachers. Using an online open-source Content Management System (CMS), researchers collected links to the target transmedia resources, organized by week. (For an image of the site, see Appendix G: CMS Site that Supported the PBS KIDS Transmedia Math Supplement on page 58.) The website provided a "walled garden," allowing access to the study's online games and videos and eliminating distractions by removing access to non-study games and videos. (For an image of the "walled garden" approach, see Appendix G: CMS Site that Supported the PBS KIDS Transmedia Math Supplement on page 58.) By using a CMS to house the videos and games, the research team also was able to provide teachers direct access to these resources without additional materials such as DVDs or flash drives. Additionally, by streaming games from the PBS KIDS Lab site via the study-specific website, researchers were able to create unique user logins and track use of the various transmedia assets by classroom.

Teachers in the Technology & Media condition gained access to PBS transmedia resources through public websites, such as www.pbskids.org/lab.

Teacher Supports and Coaching

Prior to implementing the PBS KIDS Transmedia Math Supplement, teachers were required to participate in professional development sessions conducted by evaluation team members. These sessions consisted of one three- to four-hour Saturday session and another three-hour session during the same week, with instructional coaches encouraged to attend to meet their teachers and familiarize themselves with the training their teachers received.

The sessions were designed to introduce teachers to:

- the target mathematics skills contained in the PBS KIDS Transmedia Math Supplement (counting and subitizing; identifying numerals; recognizing, composing, and representing shapes; and patterning);
- activities that composed the 10-week PBS KIDS Transmedia Math Supplement;
- instructional strategies for using the PBS KIDS Transmedia Math Supplement activities to support children's mathematics learning;
- the Teacher's Guide that detailed the 10-week PBS KIDS Transmedia Math Supplement;
- the media and technology resources, and the principles behind how they were integrated into early mathematics teaching and learning activities; and
- what teachers could expect from their instructional coach, as well as what their coach would expect of them.

Technology & Media condition teachers also attended pre-study training that was similar in format and duration to that of the Transmedia condition.

The purpose of these sessions was to introduce teachers to:

- mathematics skills to consider targeting in their classrooms (counting and subitizing; identifying numerals; recognizing, composing, and representing shapes; patterning; measurement; and documenting and analyzing data);
- a suggested schedule for integrating mathematics and digital content into their 10-week study experience;
- instructional strategies to help support children's mathematics learning with and without technology and media;
- a brief Teacher's Guide in support of their integration efforts, including pointers to online resources;
- the technology resources they were being asked to integrate into their classrooms; and
- what they could expect from their coach, as well as what their coach would expect of them.

Additionally, during the 10-week study period both PBS KIDS Transmedia Math Supplement and Technology & Media condition teachers received on-site support from an instructional coach hired and trained by the research team. The purpose of coaching was to help teachers translate into classroom practice the principles and strategies presented in the professional development sessions and outlined in the guides provided to teachers in each of these conditions. The coaching component, which included support to teachers during planning and implementing lessons, allowed the coach to provide targeted feedback tailored to the specific needs of the teacher.

The research team provided professional development opportunities for Business as Usual teachers at the conclusion of study activities in the form of a self-paced online professional development course from PBS *TeacherLine*. Teachers were enrolled in a course, "Encouraging Mathematical Communication Skills," that aimed to help teachers develop communication skills to support children's mathematical thinking and learning.

Study's Grounding in Prior Research

This section describes the base of prior research on which this study is built.

Approach to Early Mathematics Instruction

Findings from the research team's 2012 Prekindergarten Transmedia Math Pilot Study and prior research (e.g., Balfanz, Ginsburg, & Greenes, 2003; Ginsburg, Choi, Lopez, Netley, & Chi, 1997) suggest that young children, including those in low-income communities, already use mathematical thinking and are able to develop new mathematical skills and knowledge. Additionally, findings from the 2012 Pilot Study confirmed that well-trained preschool teachers are able to guide mathematics experiences to support learning, and that children living in traditionally under-resourced communities often do not have access to a stimulating and challenging preschool learning environment that would support their early mathematics learning (Ginsburg et al., 2008). This research influenced the approach to early mathematics instruction that guided the development of the PBS KIDS Transmedia Math Supplement for the current study.

Specifically, the content and sequencing of the PBS KIDS Transmedia Math Supplement drew on the work of Herb Ginsburg (Ginsburg et al., 2003), Julie Sarama, and Doug Clements (Sarama & Clements, 2004). In particular, the Clements and Sarama Building Blocks curriculum (Sarama & Clements, 2004) provided strong examples of how to introduce and sequence mathematics skills that preschool teachers are comfortable addressing and with which they tend to be less experienced. Ginsburg's Big Mathematics for Little Kids (Ginsburg et al., 2003) provided evidence-based examples of developmentally appropriate

mathematics topics, skills, and activities. Using these curricula as a guide—along with the *Ready To Learn*/PBS KIDS transmedia properties available at the time of the PBS KIDS Transmedia Math Supplement creation—the targeted mathematics skills included in the curriculum supplement are: counting; subitizing; recognizing numerals; recognizing, composing, and representing shapes; and patterning. These skills were combined using a spiral curriculum model (Bruner, 1960), where teachers introduce content and skills and then provide repeated and increasingly sophisticated activities for children to understand, practice, refine, and master previously introduced material.

The 2009 CPB-PBS *Ready To Learn* randomized controlled trial (Penuel et al., 2009) provided the theoretical grounding for the approach used in creating the PBS KIDS Transmedia Math Supplement. By evaluating the approach further during the 2012 Preschool Pilot Study of PBS KIDS Transmedia Mathematics Content (EDC & SRI, 2012), the research team confirmed that the combination of transmedia-supported and hands-on activities in a thoughtful sequence worked well in supporting teachers' use of technology and transmedia for mathematics instruction.

Approach to Transmedia and Technology

In recent years, the early learning community has adopted a pragmatic stance toward using digital technologies to support learning at the preschool level. There is a growing recognition that digital media and technology may be used in educationally unique and developmentally appropriate ways by children, often with the wise guidance of parents and teachers (NAEYC/Fred Rogers Center, 2012). Still, while K–12 teachers often embrace technology, preschool teachers are less experienced with, and have limited access to digital tools. In fact, only slightly more than half of preschool teachers report having a computer in their classroom, and most of these are non-touch screen and require young children to navigate external mice and keyboards (McManis & Gunnewig, 2012). Moreover, preschool teachers are unfamiliar with how to integrate technology into instruction (Davidson et al., 2009). Consequently, even available technology that is responsive to the ages and developmental levels of the children is less likely to be used. While use of these resources is less common in preschool, there is strong evidence for the effectiveness of public media content to support early learning.

Past research has shown that developmentally appropriate PBS media and technology resources have particular strengths and affordances that make them powerful tools for teaching and learning at the preschool level. Public media programs have been shown to successfully recruit and sustain young children's engagement, which in turn promotes learning across a range of domains, including mathematics (Fisch, 2004; Fisch & Truglio, 2001; Thakkar, Garrison, & Christakis, 2006, Penuel et al, 2009). Recent research also has shown that computer use can support increases in young children's social, cognitive, and language skills, in addition to literacy and mathematics skills, and that touch screen technologies (e.g., interactive whiteboards) have the potential to foster greater collaboration and subsequent learning among preschoolers (McManis & Gunnewig, 2012).

This study builds on the work of McManis and Gunnewig (2012), who found that adult presence and guidance was required in order to make educational use of technology in early learning, and integrates researcher-selected transmedia content in a guiding framework for use by teachers and their children. McManis and Gunnewig note that adults play a dual role when supporting young children's engagement with technology: They guide the use of the technology by children, and also promote peer-to-peer interaction around technology use. This study examines how to support adults in both these roles by providing guidance about how to integrate the use of technology and transmedia into instructional mathematics activities, and how to engage children in discussions using technology as a jumping-off point. The experiences were designed from the perspective that media and technology resources have particular strengths and affordances for learning, and are powerful tools for teaching, but are most valuable when thoughtfully sequenced to complement and enrich established routines and activities by teachers who are informed and provided with adequate resources and materials.

Approach to Professional Development and Coaching

Numerous studies suggest that successful implementation of new practices in the classroom requires professional development, support, and just-in-time guidance for teachers (Ackerman, 2008; Bowman, Donovan, & Burns, 2001; Chen & Chang, 2006; Poglinco & Bach, 2004). Thus, in the current study, the research team created a coaching model where "expert instructors" supported preschool teachers in their efforts throughout the course of study activities. The type of support provided was guided by findings from the evaluation team's *2009 Ready To Learn literacy study* (Penuel et al., 2009) as well as its 2012 Prekindergarten Transmedia Math Pilot Study (EDC & SRI, 2012) indicating that professional development, both prior to and targeted specifically to study activities, was an integral part of successful implementation of novel curriculum supplements.

In the current study, the research team created a professional development and coaching model in which teachers in both the PBS KIDS Transmedia Math Supplement group and Technology & Media group received professional development prior to implementing any study activities, along with ongoing support for their efforts by an instructional coach. See Appendix H: Professional Development Model Included in the PBS KIDS Transmedia Math Supplement on page 60.

Results

This section describes study results for children, teachers, and implementation, and includes methodology and the analytic approach for each.

Child Outcomes

A principal goal of this randomized controlled trial was to evaluate the efficacy of the PBS KIDS Transmedia Math Supplement and the Technology & Media condition by examining their impact on young children's learning.

Main findings include:

- Children in the PBS KIDS Transmedia Math Supplement condition improved significantly in their understanding of the targeted early mathematics skills—counting, number recognition and subitizing, shapes, and patterns—compared to children in the Business as Usual condition as measured by the supplement-based assessment.

- Children in the Technology & Media condition did not improve on the target mathematics skills significantly compared to children in the Business as Usual condition.

- There was no significant finding related to self-regulation as measured by the Head-Toes-Knees-Shoulders self-regulation assessment for children in any condition in the study.

Method

To assess children's mathematics outcomes, the research team administered two early mathematics assessments: a short version of the Research Based Early Mathematics Assessment (REMA short form) (Weiland et al., 2012), which served as a standardized assessment of children's mathematics skills, and a supplement-based assessment (SBA) developed by the research team to be closely aligned to the mathematics concepts targeted in the PBS KIDS Transmedia Math Supplement and the Technology & Media conditions. In addition, to assess children's self-regulation, the research team administered the Head-Toes- Knees-Shoulders (HTKS) measure (Ponitz et al., 2008), a recently developed and validated measure of young children's behavioral self-regulation. Fuller descriptions of these three measures appear below.

Trained assessors administered the three assessments to children in all three conditions prior to the beginning of the study and again after the completion of the study. Assessors administered the REMA on one day and the SBA and HSKT together on another day to avoid fatiguing the children. Each session lasted approximately 20 to 30 minutes. The research team randomly assigned assessment order to avoid unintended order effects.

Standardized Assessment of Mathematics

The short version of the REMA was recently developed by Weiland et al. (2012) based on the full REMA (Clements, Sarama, & Lui, 2008), which was designed to assess children's mathematics learning in prekindergarten through second grade. The short version of the REMA measures preschool and kindergarten children's early numeracy and geometry skills. The 19 items selected to be part of the short version of the REMA assess mathematics skills that are considered essential in preschool and kindergarten (NGA/CCSSO, 2010; Clements & Sarama, 2009)—recognition of number and subitizing, composition of number, comparison and sequencing, counting, numeral identification, arithmetic, shape 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 are required to provide a verbal response, point, or engage with manipulatives. Rasch analysis conducted on the short version of the REMA provides evidence of high item reliability (approximately 1.00) and high person reliability (ranging from 0.68 to 0.76) (Weiland et al., 2012). Findings also indicate that the assessment is sensitive to detect differences in young children's mathematics ability levels and has adequate concurrent validity (correlations of 0.74 were reported with the full version of the REMA and the Woodcock Johnson Applied Problem subtest) and adequate discriminant validity (correlations of 0.64 were reported with the Peabody Picture Vocabulary Test 3rd Edition and the Letter Word Identification subscale of the Oral Language Scale). Finally, differential item functioning (DIF) analysis for gender, home language, and socioeconomic status across different samples indicated that there is no DIF in the short version of the REMA.

Supplement-Based Assessment of Mathematics

To assess children's understanding of the concepts and activities included in the PBS KIDS Transmedia Math Supplement, the research team developed a supplement-based assessment (SBA) during the 2012 Pilot Study. Using information gathered from that study, and taking into account revisions to the curriculum supplement for the current study, a revised version of the SBA was used to assess children's understanding of counting, number recognition and subitizing, shapes, and patterns. As in the REMA, items in the SBA involve game-like activities that require assessors to read a verbal prompt and children to provide a verbal response, point, or engage with manipulatives. The 20 items included in the SBA are aligned to the concepts and activities included in the PBS KIDS Transmedia Math Supplement. A team of early childhood researchers with experience in assessment developed and reviewed the SBA items and suggested revisions. Once items had been revised, the research team pilot-tested them on a small sample of preschool children and revised them as necessary. The evaluation team used data from the current study to examine item total correlations and found them to be higher than .2, with the majority ranging from .4 to .7. Analysis of SBA data also indicates high levels of internal consistency (Cronbach alphas were .90 and .89 for pre- and post-test, respectively).

Standardized Assessment of Self-Regulation

The Head-Toes-Knees-Shoulders (HTKS) was developed as a more complex version of the Head-to-Toes Task that was designed to measure children's behavioral self-regulation. The Head-to-Toes Task involves asking children to follow a command (e.g., "Touch your toes") and then asking them to respond with a conflicting or nonautomatic response (e.g., "When I say 'Touch your toes,' touch your head"). The HTKS starts off with these two commands ("Touch your toes" and "Touch your head") and slowly becomes more complex by introducing two other commands ("Touch your shoulders" and "Touch your knees"). The HTKS requires children to use multiple cognitive skills, such as remembering rules and attending to verbal commands, and then applying them to their behavioral response. "These demands may be similar to those in classrooms, when children need to follow multiple instructions and finish one project before starting another or remember to raise their hand before participating" (Mathews, Ponitz, & Morrison, 2009, p. 693). Studies using the Head-to-Toes and HTKS have reported high interrater reliability (e.g., Connor et al., 2010; Ponitz, McClelland, Matthews, & Morrison, 2009; Wanless, McClelland, Acock, Chen, & Chen, 2011). Studies also have found that higher behavioral regulation (measured using the HTKS) is predictive of later mathematics and literacy achievement in early childhood (Ponitz et al., 2009; Wanless et al., 2011).

Data Analytic Approach

To answer the study's research questions, the evaluation team conducted a series of descriptive analyses and a series of multilevel analyses to examine young children's learning in the PBS KIDS Transmedia Math Supplement and Technology & Media conditions, relative to young children's learning in a Business as Usual group which implemented their existing practices.

To determine the minimal detectable effect size (MDES) with power of .80, the research team conducted a statistical power analysis using methods outlined in Schochet (2008). Several important parameters must be derived to carry out sample size calculations in multilevel models: the intraclass correlation (ICC), which is the proportion of variance in outcome scores attributable to between-classroom variability; the number of clusters (classrooms); the number of children per classroom; and the proportion of variance that can be accounted for by covariates, which can significantly increase the precision of the estimates if covariates are correlated with the outcome (Spybrook, Raudenbush, Congdon, & Martínez, 2009). With the sample of 30 classrooms per condition (and 10 children assessed per classroom), and assuming that $\alpha = .05$, ICC = .22 (based on previous studies using similar measures; Hedges & Hedberg, 2007) child- and classroom-level covariates explain approximately 65% of the student and 82% of the class-level variance in the outcome (also based on the previous studies cited above), the minimum detectable effect size (MDES) with power of .80 would be .19.

Prior to conducting multilevel models to examine the impact of the PBS KIDS Transmedia Math Supplement and the Technology & Media conditions on young children's learning, the research team examined attrition patterns and baseline equivalence. Researchers followed analysis procedures designed to align with What Works Clearinghouse (WWC) standards for evidence quality. (Detailed attrition and baseline equivalence analyses, a discussion of the anomalies in the HTKS measure and a discussion of heteroskedasticity are in Appendix I: Detailed Analysis on page 61.)

The research team estimated main effects by conducting three-level multilevel models (students nested within classrooms and classrooms nested within centers) using the Stata software environment (version 12) and the mixed command using full maximum likelihood estimation. The full specification of the main impact models is shown in Table 5.

Table 5. Main Treatment Impact HLM Specification

$$\text{Postest}_{ijk} = \beta_0 + \beta_1 I\_treatment_{jk} + \beta_2 I\_technology_{jk} + \beta_3 Pretest\_centered_{ijk}$$

$$+ \beta_4 \overline{Class\_Pretest\_centered}_{jk} + e_{ijk} + r_{jk} + u_k$$

Where

$Posttest_{ijk}$ ..... is the posttest score for student *i* within classroom *j* and center *k*.

$Pretest\ centered_{ijk}$ ..... is the grand mean-centered pretest score for student *i* within classroom *j* and center *k*.

$Class,\ Pretest\ centered_{jk}$ ..... grand mean centered pretest score for classroom *j* within center *k*.

$I\_treatment_{jk}$ ..... is an indicator for the treatment condition (1 = treatment, 0 = not treatment) of classroom j in center *k*.

$I\_technology_{jk}$ ..... is an indicator for the technology condition (1 = technology, 0 = not technology) classroom *j* in center *k*.

b_0 ..... is the intercept and estimates the expected posttest score given a mean score on the pretest in the control condition.

b_1 ..... is the estimate of the effect between the treatment and control conditions.

b_2 ..... is the estimate of the effect between the technology and control conditions.

e_{ijk}, r_{ijk}, u_k ..... are random error terms at the student, teacher, and center levels, respectively.

Researchers note that the coefficients b_1 and b_2 are estimated in the score point metric of whatever assessment is being fit within the model. In order to report the impacts on three different assessments in a comparable scale, all impacts are converted to the standardized effect size metric known as *Hedges' g*. Scatter plots of post-test versus pre-test measures and lines of best fit were examined for unusual distributions, outliers, and homogeneity of variance.

In addition to examining main effect, the research team also investigated potential moderation effects by pre-test score and child age. In other words, researchers examined whether the treatment effect varied for children with higher vs. lower pre-test scores or for older vs. younger children. To evaluate potential moderation effects, interaction terms between the treatment indicators and the moderator were added and tested for statistical significance.

Results

Child Outcomes

Children who participated in the PBS KIDS Transmedia Math Supplement condition learned significantly more mathematics than did children in the Business as Usual condition.

Significant main effects were detected only for the PBS KIDS Transmedia Math Supplement condition. After implementation, children in the PBS KIDS Transmedia Math Supplement condition exhibited significantly higher SBA scores than did children in the Business as Usual condition (1.51 points, effect size of 0.24, $p<.001$). This means that being in the PBS KIDS Transmedia Math Supplement condition would lead to a 9% increase in percentile rank for an average student in the Business as Usual group. A trend, or marginally significant effect, also was detected using the REMA data. After implementation, children in the PBS KIDS Transmedia Math Supplement condition exhibited higher REMA scores than did children in the Business as Usual condition (1.09 points, effect size of .15 and $p < .07$)[3].

No significant effects were detected for HSKT scores.

The effects of the Technology & Media condition relative to the Business as Usual condition were all small and not statistically significant.

A summary table of the main effects model results follows (see Table 6). Tables of the full model specification and parameters appear in Appendix I: Detailed Analysis.

While not statistically significant, findings indicate that the PBS KIDS Transmedia Math Supplement may have a greater benefit to those children who scored lowest on the supplement based assessment.

One significant and one marginally significant moderation effect was found with pre-test in the SBA models. However, when accounting for inflated Type I error due to multiple comparisons, these effects are no longer significant or marginally significant. Although non-significant due to multiple comparisons, these effects merit further exploration. Appendix I: Detailed Analysis includes a table detailing both main and moderating effects as well as visual representation of moderator effects to aid interpretation.

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3 Under NCES Statistical Standards, standard 5-1-5, "If the significance is between .05 and .10, and the observed differences are believed to be real, based on research or other evidence, but are not significant at the .05 level, possibly associated with small sample sizes and/or large standard errors, this may be noted" (National Center for Educational Statistics, 2003).

Table 6. 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	---
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	---
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	---

*Note: thresholds for statistical significance adjusted for six pair-wise comparisons using the Benjamini-Hochberg False Discover Rate procedure.

Teacher Outcomes

Method

Teachers in all three conditions completed a teacher survey prior to the professional development session conducted at the beginning of the study, and then again at the end of the study. The teacher survey used in the current study was an iteration of the survey administered during the 2012 Prekindergarten Transmedia Mathematics Pilot (EDC & SRI, 2012).

Both administrations of the surveys included questions about beliefs, attitudes, and practices around mathematics and technology use and integration. The Early Math Collaborative at the Erikson Institute developed the questions about beliefs, attitudes, and practices around mathematics (Chen & McCray, 2012). In these questions, teachers are asked to rate a series of statements on a 10-point Likert scale (where 0 = strongly disagree and 10 = strongly agree). The research team developed the questions about technology use and integration based on literature reviews and a review of relevant surveys. The survey teachers completed prior to the study also included questions about their background and experience. The survey completed at the end of the study included questions about their experiences during and reflections after the study.

Data Analytic Approach

To examine the quantitative data collected in the survey, the research team conducted descriptive analysis by calculating frequencies and percentages for the binomial, categorical, and ordinal data, and means and standard deviations for the continuous data. For items included in both survey administrations, researchers conducted multilevel models that examined whether teachers' responses pre- and post-administration were significantly different, and whether these differences varied by condition (PBS KIDS Transmedia Math Supplement vs. Business as Usual; Technology & Media vs. Business as Usual). To identify patterns in the qualitative responses, researchers examined all open-ended questions to develop potential coding categories. Open-ended responses were then coded to identify meaningful patterns that could inform findings.

Results

More PBS KIDS Transmedia Math Supplement teachers reported an increased focus on numeracy and patterns, relative to Business as Usual teachers.

There was a significant increase in the proportion of teachers who reported promoting numeracy skills across time in the PBS KIDS Transmedia Math Supplement condition (84% of teachers reported doing so in the pre-survey, and 100% reported doing so in the post-survey) relative to the Business as Usual condition (94% of teachers reported doing so in both the pre- and post- surveys) ($b = .17$, $z = 2.11$, $p < .05$). While the lack of change observed in the Business as Usual condition might be due to regression toward the mean, the fact that 100% of teachers in the PBS KIDS Transmedia Math Supplement condition reported teaching numeracy skills at the completion of the study is noteworthy. Likewise, there was a significantly larger increase in the proportion of teachers who reported promoting patterns across time in the PBS KIDS Transmedia Math Supplement condition relative to the Business as Usual condition. The proportion of teachers increased from 80% to 98% in the PBS KIDS Transmedia Math Supplement condition, compared to 87% to 92% in the Business as Usual condition ($b = .16$, $z = 1.99$, $p < .05$).

PBS KIDS Transmedia Math Supplement and Technology & Media condition teachers used study technologies to promote mathematics learning.

The proportion of teachers who reported using technology to teach mathematics concepts increased significantly more in both the PBS KIDS Transmedia Math Supplement and Technology & Media conditions, relative to the Business as Usual condition. This was true for every mathematics concept listed in the survey. The table below shows the proportion of teachers who reported teaching each mathematics concept using technology (asterisks indicate whether the increase was significantly greater than that in the Business as Usual condition).

Table 7. Proportion of teachers who reported teaching mathematics 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% *

*$p<.05$, ** $p<.001$

The proportion of teachers who reported using videos, laptop computers, and interactive whiteboards specifically also increased significantly more in both the PBS KIDS Transmedia Math Supplement and Technology & Media conditions, relative to the Business as Usual condition. Conversely, the proportion of teachers who reported using desktop computers decreased in the PBS KIDS Transmedia Math Supplement, relative to the Business as Usual condition ($b = -.37$, $z = 2.26$, $p < .05$).

PBS KIDS Transmedia Math Supplement teachers' beliefs about their mathematics knowledge, and the benefits of technology for preschoolers improved after the study.

PBS KIDS Transmedia Math Supplement teachers reported greater increases in their understanding of the concepts of number/operations and geometry relative to Business as Usual teachers ($p<.05$). In the PBS KIDS Transmedia Math Supplement condition, the proportion of teachers who strongly agreed with the statement, "I understand the concepts of number and operations as they apply to my students," increased from 27% to 38%, while the proportion of Business as Usual condition teachers who strongly agreed decreased from 46% to 36% ($b = .37$, $z = 2.26$, $p < .05$). Similarly, the proportion of PBS KIDS Transmedia Math Supplement teachers who strongly agreed with the statement, "I understand the basic concepts of geometry that apply to my students," increased from 16% to 40%, whereas it increased from 35% to only 38% for teachers in the Business as Usual condition ($b = .38$, $z = 2.26$, $p < .05$). See Figures 1 and 2.

Figure 1. Agreement level with the statement, "I understand the concepts of number and operations as they apply to my students"

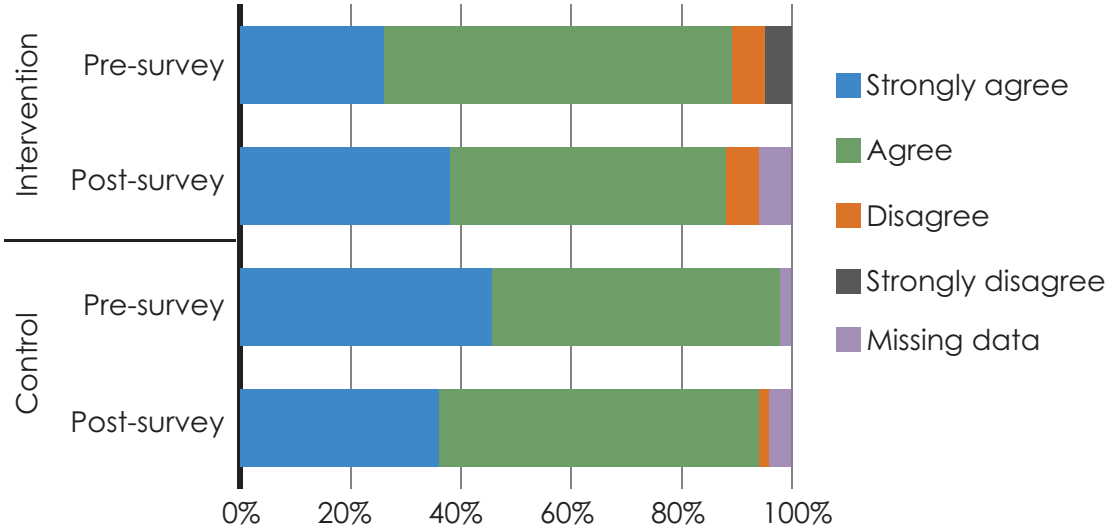
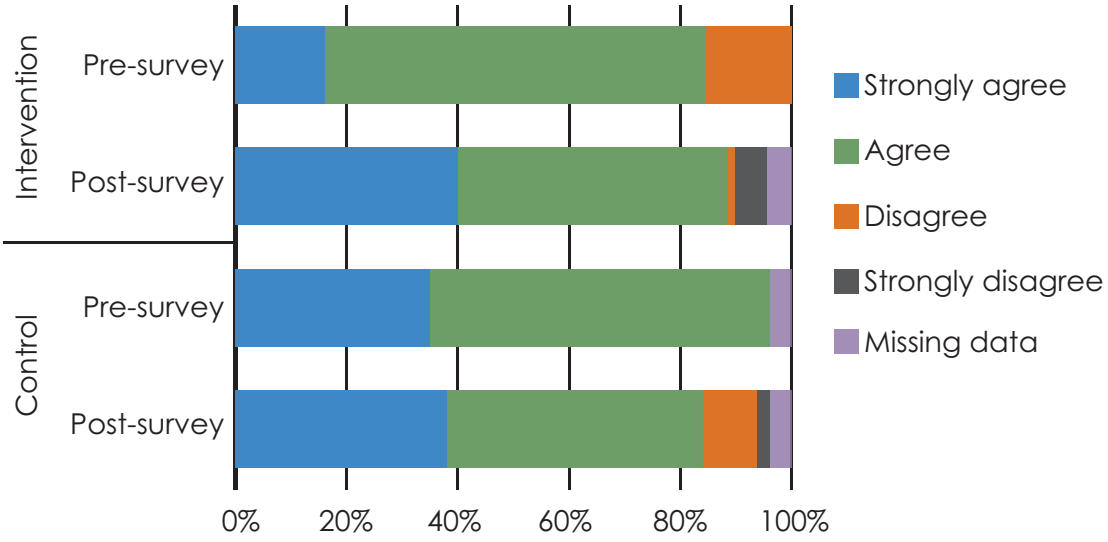


Figure 2. I understand the basic concepts of geometry that apply to my students



PBS KIDS Transmedia Math Supplement teachers also reported greater positive changes in their beliefs about the impact of technology on children (b = .29, z = 2.68, p < .01). The proportion of PBS KIDS Transmedia Math Supplement teachers who strongly agreed with the statement, "New technology encourages learning by connecting children to resources about topics they are curious about," increased from 11% to 30% in the PBS KIDS Transmedia Math Supplement while it decreased from 26% to 19% in the Business as Usual condition. Similarly, the proportion of teachers agreeing strongly with the statement, "New technology helps children acquire technology skills they will need in school and life," increased from 25% to 45% in the PBS KIDS Transmedia Math Supplement condition, while it decreased from 42% to 38% in the Business as Usual condition (b = .27, z = 1.99, p < .05).

Figure 3. Agreement level with the statement, "New technology encourages learning by connecting children to resources about topics they are curious about."

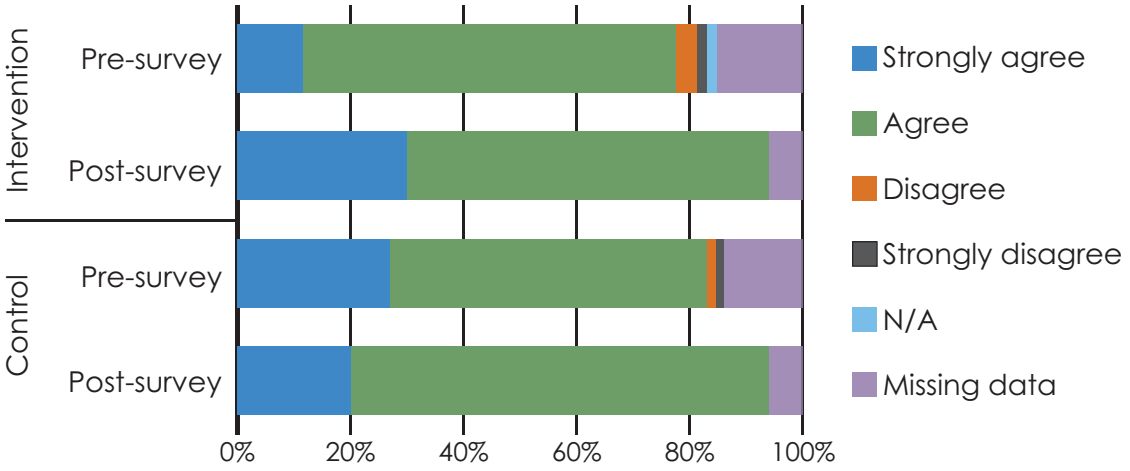
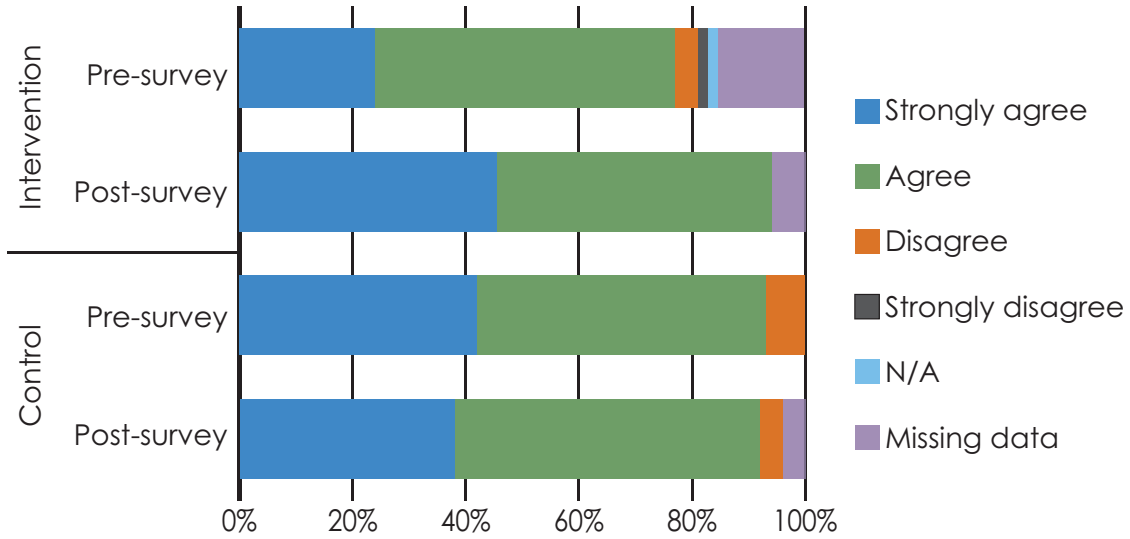


Figure 4. Agreement level with the statement, "New technology helps children acquire technology skills they will need in school and life."



Most study teachers reported continuing with their regular math instructional practices during the study, and teachers in the PBS KIDS Transmedia Math Supplement group spent more time on mathematics instruction relative to teachers in the Business as Usual group.

Some teachers received mathematics professional development apart from the PD provided as part of the study. According to the post-survey, about 13% of the participating teachers participated in some other mathematics PD during the study. The proportion of the teachers who participated in some other mathematics PD was not significantly different between the PBS KIDS Transmedia Math Supplement and Business as Usual conditions, nor between the Technology & Media and Business as Usual conditions.

On average, 89% of teachers said they continued with their regular math instructional activities during the study. PBS KIDS Transmedia Math Supplement teachers reported a greater increase in the time spent on mathematics activities relative to Business as Usual teachers ($b = 3.7$, $z = 2.47$, $p < .05$); PBS KIDS Transmedia Math Supplement teachers increased from 2 to 7 hours per week on average, while Business as Usual teachers increased from 2 to 4 hours per week on average.

Implementation Outcomes

Methods

The analyses of implementation data paint a picture of how digital media-supported early mathematics teaching and learning activities unfolded in PBS KIDS Transmedia Math Supplement and Technology & Media classrooms. Aside from highlighting contrasts across classrooms in all three study conditions with respect to mathematics instruction, they also provide a context for findings related to child and teacher outcomes described above.

The evaluation team used four integrated data collection activities to document the implementation of mathematics teaching and learning activities and to describe the contrasts related to mathematics instruction and the use of technology and media across the PBS KIDS Transmedia Math Supplement, Technology & Media, and Business as Usual classrooms. These comprise weekly classroom logs, weekly coach logs, fidelity observations, and quality observations. The following sections describe the design of these research activities in detail.

Table 8. Implementation data collection activities by condition

Data Source	PBS KIDS Transmedia Math Supplement	Technology & Media	Business as Usual
Weekly Classroom Logs Completed by teachers	✓	✓	✓
Weekly Coach Logs	✓	✓	--
Fidelity observations Completed by coaches in all PBS KIDS Transmedia Math Supplement classrooms	✓	--	--
Quality observations Completed by independent observers in 6 PBS KIDS Transmedia Math Supplement, Technology & Media, and Control classrooms (N = 18)	✓	✓	✓

Weekly Classroom and Coach Logs

All participating teachers in the PBS KIDS Transmedia Math Supplement, Technology & Media, and Business as Usual conditions completed weekly classroom logs to document the mathematics instruction occurring in study classrooms. Constructed as paper-and-pencil surveys that teachers filled out at the end of the instructional week, the classroom logs included items relating to the dosage of mathematics (the quantity of time spent on mathematics and the skills addressed). Additionally, PBS KIDS Transmedia Math Supplement teachers provided information about the implementation of the PBS KIDS Transmedia Math Supplement, including the extent to which they modified activities, while teachers in Technology & Media classrooms provided information about their use of technology and media resources. Both groups of teachers described the challenges they encountered while integrating media and technology and the types of support they received from coaches.

Coach logs, which were completed by all coaches participating in the study (assigned to classrooms in the PBS KIDS Transmedia Math Supplement and Technology & Media conditions), gathered information about the frequency, length, and type of contact between coaches and teachers in these classrooms, the challenges that coaches observed teachers encountering while enacting curriculum supplement activities (PBS KIDS Transmedia Math Supplement classrooms) or integrating media and technology (PBS KIDS Transmedia Math Supplement and Technology & Media classrooms), and the types of support that coaches provided to teachers in both groups.

Researchers conducted descriptive analysis of the quantitative items on the classroom and coach logs, computing frequencies or calculating means and standard deviations as appropriate. Additionally, the research team also examined contrasts across PBS KIDS Transmedia Math Supplement and Business

as Usual conditions, and Technology & Media and Business as Usual conditions for the items where it was appropriate. Where available and appropriate, qualitative data help illustrate findings.

Fidelity Observations

Four observations were conducted in each PBS KIDS Transmedia Math Supplement classroom to document the extent to which classroom enactment of activities occurred with fidelity to the intervention as described in the Teacher's Guide and professional development sessions. Instructional coaches assigned to PBS KIDS Transmedia Math Supplement classrooms conducted observations in the classrooms in which they provided coaching during Weeks 4 through 9 of the implementation period.

Four activities were selected for fidelity observations: Video Co-viewing, Challenge Game Play, Math Circle Routine, and Guided Book Reading, as these were activities for which the PBS KIDS Transmedia Math Supplement provided substantial pedagogical guidance. For each activity, the research team identified dimensions of fidelity and developed items to document the relationship between classroom enactment and the planned intervention. The fidelity observation instrument consisted of items that applied across activity types as well as items that were specific to individual activities. For example, fidelity observation items for all activities focused on the enactment of the "warm up"—whether teachers provided an introduction to the activity, reviewed the central mathematics skill(s), used real world examples, and offered children opportunities to contribute to the discussion—while the enactment of pause points was specific to Video Co-viewing and Guided Book Reading activities.

The quantitative data collected through the fidelity observations were analyzed to identify frequencies or means and standard deviations, as appropriate. The fidelity observation data analysis also examined the extent of variation within classrooms, across the different activity types, as well as across classrooms. Similar to the coach and classroom logs, qualitative items helped provide examples for the patterns of fidelity of implementation.

Quality Observations

Researchers conducted quality observations in a randomly selected subset of six classrooms in each of the three conditions (for a total of 18 classrooms) to describe patterns of mathematics learning opportunities present in study classrooms and identify contrasts, if any, with respect to aspects of mathematics instruction across PBS KIDS Transmedia Math Supplement, Technology & Media, and Business as Usual conditions. Observations took place during implementation Weeks 6, 7, and 8. A total of three observations were conducted in each classroom by independent observers.

The quality observation instrument comprised two sections. The Classroom Culture section included items that helped describe the classroom environment as a whole, while the Specific Math Activity (SMA) section, focused on mathematics teaching and learning, documented individual mathematics activities occurring during the observation period. The SMA section comprised a number of items

focused on mathematics instructional practice (e.g., strategies used to support children's mathematical understanding, use of mathematical talk, inviting and building on children's mathematical contributions) that were rated on a Likert scale. The Classroom Observation of Early Mathematics—Environment and Teaching (Sarama & Clements, 2010) was the starting point for the development of the quality observation instrument.

The research team aggregated ratings for the SMAs, using them as the basis for organizing classrooms in the observation sample into tertiles. Researchers then examined the classrooms in each tertile; the aim was to identify mathematics instructional practices teachers enacted consistently as well as the practices that were absent or appeared more challenging for teachers. The evaluation team also was interested in comparing classrooms in the three conditions and identifying contrasts when present. Because quality observations were conducted only in a small sample of study classrooms, these analyses are exploratory and may not generalize to the overall study sample.

Data Collection

Implementation data were collected from participating study classrooms on an ongoing basis. Participating teachers and coaches completed weekly classroom and coach logs during all 10 weeks of implementation; three fidelity observations were conducted during Weeks 4 through 9 in all PBS KIDS Transmedia Math Supplement classrooms; and three quality observations were conducted in a sample of 18 participating classrooms (6 each from the PBS KIDS Transmedia Math Supplement, Technology & Media, and Business as Usual conditions) during Weeks 6,7, and 8 of the implementation period.

Response rates for coach and teacher logs were higher than 95 percent, indicating that patterns of implementation inferred from the logs can be applied to the entire sample. Coaches and observers who conducted the fidelity and quality observations were trained in the use of the instruments and data collection procedures. For the quality observations, the training included a "guided practice" component, during which observers rated sample videos using the observation tool. Observers were required to demonstrate reliability of 70 percent or greater with an expert rater prior to data collection, and 20 percent of all quality observations were conducted by pairs of observers to ensure reliability of data on an ongoing basis.

Table 9. Implementation data collection activities

	Total	PBS KIDS Transmedia Math Supplement	Technology & Media	Business as Usual
Weekly classroom logs	860	270	300	290
Weekly coach logs	568	296	272	--
Fidelity observations	97	97	--	--
Quality observations	52	18	18	16

Results

Implementation of Transmedia-Supported Pedagogy

In general, teachers implemented the PBS KIDS Transmedia Math Supplement as intended and addressed target mathematics skills more frequently than did teachers in the other two conditions.

Teachers in all study conditions addressed target mathematics skills as well as other mathematics skills. Teachers in all three conditions commonly taught skills like counting, number identification, and patterning; however, teachers in the PBS KIDS Transmedia Math Supplement condition addressed target mathematics skills and other mathematics skills more frequently than did teachers in the Technology & Media or Business as Usual conditions. Furthermore, teachers in the PBS KIDS Transmedia Math Supplement condition seldom omitted and rarely modified activities in the PBS KIDS Transmedia Math Supplement condition. When they modified activities, it was typically to break an activity into parts, shorten or extend an activity, or conduct a whole-class activity in small groups. Teachers typically addressed the learning goals, skills, and important points of each activity, and in fact often addressed more skills than the Teacher's Guide indicated.

Teachers typically implemented the distinctive features of the curriculum supplement—the warm-up and wrap-up, the video and book reading pause points, and the instructional strategies emphasized in the professional development. For example, in only 7.22% of observations was the warm-up omitted, and in only 7.55% of observations was the wrap-up omitted. Similarly, teachers used pause points as specified in the Teacher's Guide 95% of the time for video co-viewing and 94% of the time for guided book reading, often adding additional pause points of their own. Observers noted that discussion during the pause points centered on the mathematics knowledge and skills that were highlighted in the Teacher's Guide. Moreover, observers noted the frequency of use of the recommended instructional strategies, including 89% of observed activities where modeling was used, 85% where teachers thought aloud, 73% where teachers encouraged children to think aloud, 80% where teachers re-voiced student ideas, and 58% where teachers encouraged children to provide peer feedback.

Table 10. Enactment of distinctive features of the PBS KIDS Transmedia Math Supplement*

	Video Co-viewing	Challenge Game Play	Guided Book Reading	Math Circle
Enactment of warm-up as specified in Teacher's Guide	66.67%	63.65%	59.09%	73.08%
Enactment of wrap-up as specified in Teacher's Guide	70.37%	61.54%	**	**
Enactment of pause points as specified in Teacher's Guide	95.00%	**	93.90%	**

*N = 97 Fidelity observations; ** some activities did not include a wrap-up or pause points.

Finally, the fidelity observation data also corroborate a pattern of limited modifications. Of the 97 fidelity observations conducted, coaches reported observing modifications for fewer than half the activities (46.4%). Of the activities for which modifications were reported, coaches indicated that teachers' changes, for the most part, did not conflict with the learning goal for the activity.

However, depth of implementation varied. In particular, children were not always invited to contribute their thoughts to discussions during warm-up and wrap-up activities. Although there were multiple occasions (43.3% of the observed activities) when the warm-up included full explanation, called children's attention to a real-world example, and invited children's contributions, the majority of observed activities did not offer opportunities for children to contribute to the discussion during the warm-up. Similarly, only 34.7% of the observed wrap-ups involved an opportunity for children to contribute to the discussion.

Integration of digital resources, mostly from PBS KIDS, was high for Technology & Media condition classrooms, and teachers tended to use games and videos mostly as an engaging way to practice skills rather than as a way to introduce new skills or ideas.

Analyses of classroom logs indicate that teachers in the Technology & Media condition integrated transmedia and technology into mathematics instruction with high frequency. During the 10-week implementation period, the majority of teachers reported integrating videos (73.22% of classroom logs) and digital games (89.15% of classroom logs) into mathematics teaching and learning activities. Coaches who supported teachers in identifying and selecting media resources reported that teachers drew from a variety of sources, but that the majority of resources came from PBS KIDS.

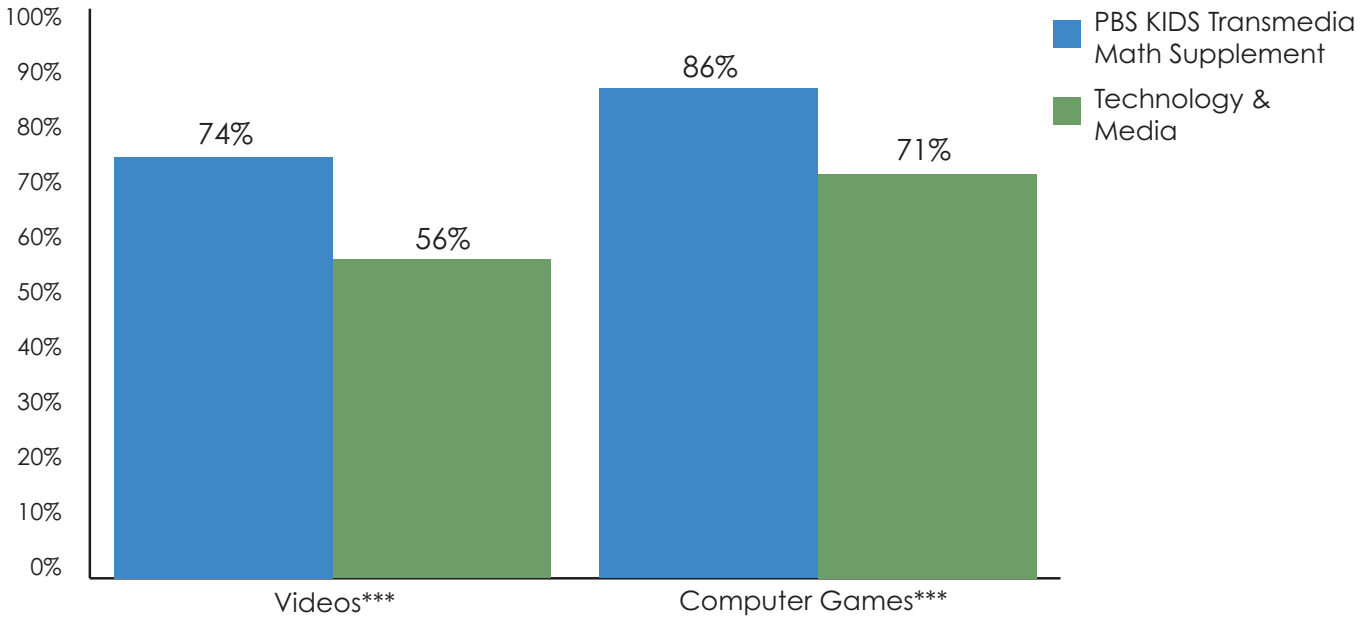
Table 11. Incorporation of transmedia into mathematics instruction (Technology & Media classrooms)

	PBS KIDS	Other Sources	N
Videos*	75.00%	57.87%	216 coach logs
Digital games*	96.96%	19.39%	263 coach logs

*Totals are greater than 100% as teachers are likely to have selected videos from PBS KIDS as well as other sources for any given week.

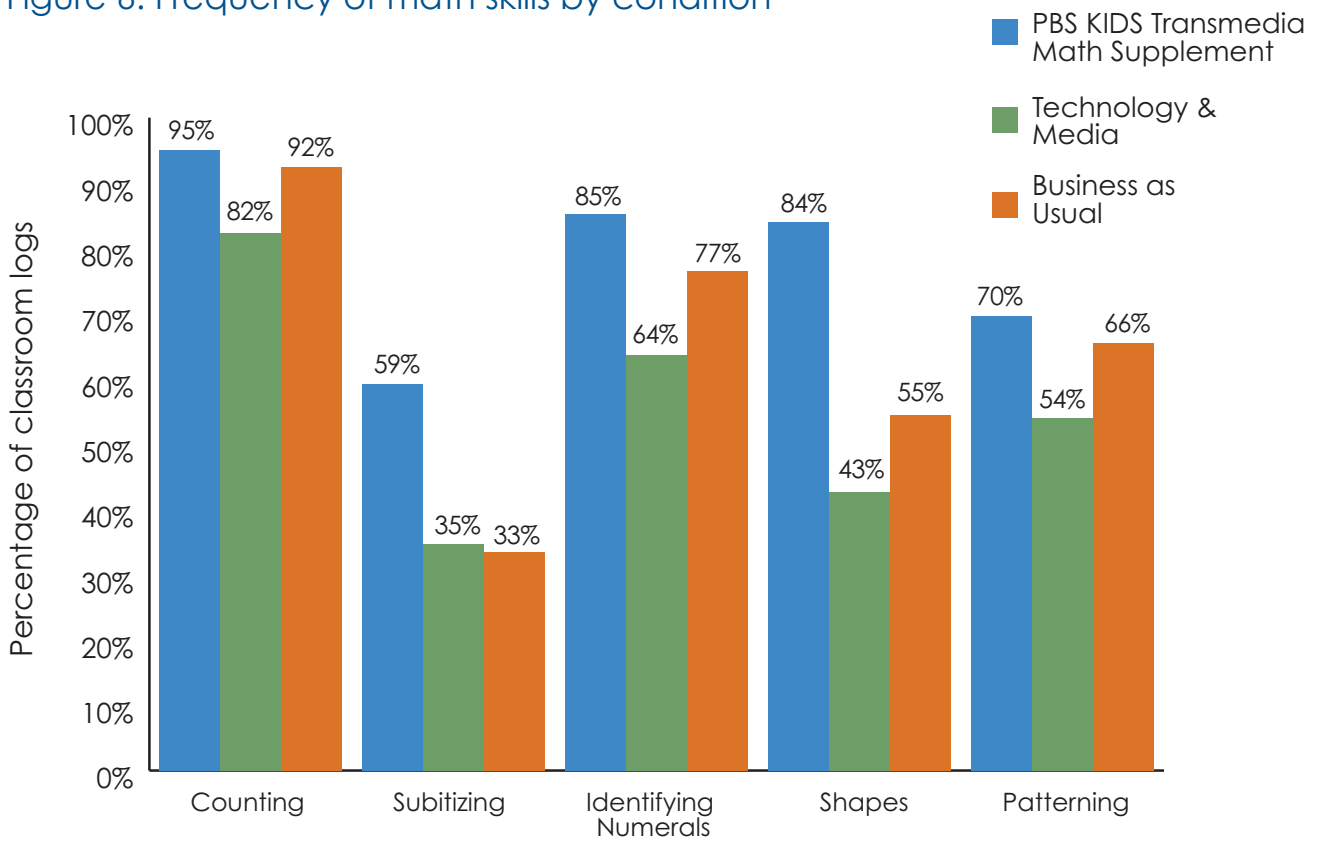
According to coaches, teachers in Technology and Media classrooms incorporated media and technology primarily to give children an opportunity to practice skills (96.14% of coach logs), ensure that instruction was more engaging for children (74.04% of coach logs) and, to a lesser extent, to provide dynamic representations of content (51.93% of coach logs). Also, teachers in PBS KIDS Transmedia Math Supplement classrooms reported using videos and computer games to a greater extent than teachers in Technology & Media classrooms (Figure 5), and the contrasts between conditions are significant.

Figure 5. Media use for mathematics instruction



**** Differences are significant; p < 0.000.*

Figure 6. Frequency of math skills by condition



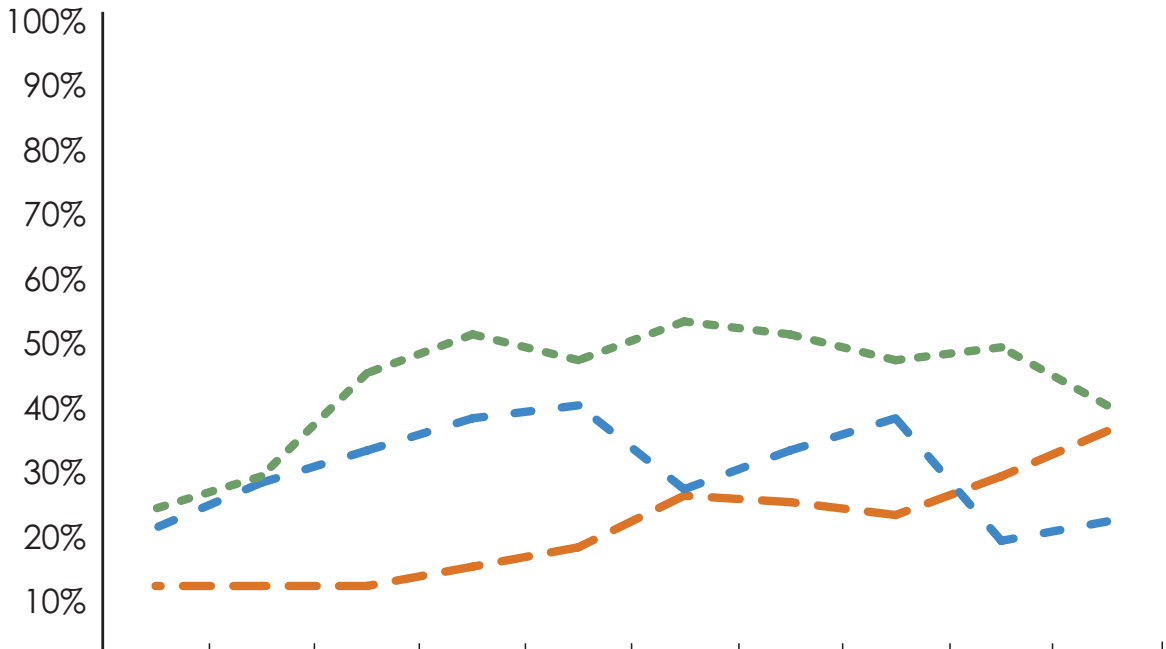
Children's Exposure to Mathematics

Teachers in all study conditions addressed target math skills and other math skills, although PBS KIDS Transmedia Math Supplement teachers addressed these skills more frequently than did teachers in the other two conditions.

In general, the target skills emphasized by the PBS KIDS Transmedia Math Supplement—counting and identifying numerals; subitizing; patterning; and recognizing, composing, and representing shapes—were addressed more frequently in PBS KIDS Transmedia Math Supplement classrooms than were other skills. Perhaps not surprisingly, these classrooms also addressed target skills with greater frequency than did Technology & Media or Business as Usual classrooms. In general, Technology & Media classrooms appeared to address target math skills less frequently than either PBS KIDS Transmedia Math Supplement or Business as Usual classrooms. Figure 6 shows the distribution of math skills addressed across classrooms in the three conditions.

Teachers in the PBS KIDS Transmedia Math Supplement condition and Technology & Media conditions reported spending more time on mathematics instruction per week than did teachers in the Business as Usual classrooms. The following graph illustrates the contrast. A greater number of teachers in PBS KIDS Transmedia Math Supplement and Technology & Media classrooms spent 4–6 hours per week on mathematics teaching and learning activities than did teachers in the Business as Usual condition.

Figure 7. Percernt of classrooms devoting 4–6 hours per week to mathematics instruction



	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
PBS KIDS Transmedia Math Supplement	23%	28%	44%	50%	46%	52%	50%	46%	48%	37%
Technology & Media	20%	27%	32%	37%	39%	26%	32%	37%	18%	21%
Business as Usual	11%	11%	11%	14%	17%	25%	24%	22%	28%	35%

Teachers' Experiences Enacting Transmedia-Supported Pedagogy

Teachers had challenges using digital resources and fitting activities into the daily schedule, which led to coaches offering frequent support. Notably, teachers in the Technology & Media condition received more on-site coach support than did teachers in the PBS KIDS Transmedia Math Supplement condition.

PBS KIDS Transmedia Math Supplement teachers reported encountering an implementation challenge almost half the time (49% of classroom logs), and coaches reported encountering an implementation challenge just over half of the time (58% of coach logs). Of the challenges reported, using media and technology and fitting the activities into the week's schedule were most common. To address these challenges, coaches assisted both PBS KIDS Transmedia Math Supplement and Technology & Media teachers in a variety of ways: with mathematics knowledge and skills, by modeling and co-leading activities, by observing instruction and providing feedback, and by assisting with materials preparation for media-rich as well as hands-on activities. Although coaches provided substantial assistance to

teachers in both conditions, teachers in the Technology & Media condition reported receiving more support (94% of classroom logs) than did PBS KIDS Transmedia Math Supplement teachers (74% of classroom logs). Teachers in the Technology & Media condition also reported an additional challenge, namely that of identifying and matching media to learning goals (19.32% of classroom logs). This finding is corroborated by the analysis of coach logs, which indicate differences between PBS KIDS Transmedia Math Supplement and Technology & Media classrooms with respect to the types of support provided by coaches (Table 12).

Table 12. Differences in coaching support between PBS KIDS Transmedia Math Supplement and Technology & Media Conditions

Types of coaching support	PBS KIDS Transmedia Math Supplement	Technology & Media
Provided support with media resources**	28.52%	55.25%
Provided support with math knowledge and skills and/ or teaching strategies**	36.50%	48.47%
Co-led activities with the teacher(s)**	11.41%	28.47%
Observed instruction and provided feedback	57.63%	49.81%

** Significant; $p < 0.00$

In both PBS KIDS Transmedia Math Supplement and Technology & Media conditions, the support provided by coaches to teachers declined during the 10-week implementation period. Although support provided to teachers diminished in both conditions, Technology & Media teachers continued to require more coaching support. Moreover, support with mathematics knowledge, skills, and instructional strategies remained at the same level throughout the implementation period among Technology & Media classrooms, while it declined in PBS KIDS Transmedia Math Supplement classrooms.

Limitations and Constraints

The study has the following limitations and constraints:

- When teaching mathematics, most preschool teachers rely on a year-long curriculum framework or one of the recently developed year-long curricula. The use of short, intensive supplementary experiences, such as the one used in this study, is rare. Compared with early mathematics curricula and curriculum frameworks available to many preschools, the PBS KIDS Transmedia Math Supplement focuses on a smaller set of mathematics skills, and relies much more on repeated experiences with technology and media resources to support children in learning early mathematics.

- The sample of children for this study was not representative of preschool children in the country as a whole. The study was conducted in urban areas, in neighborhoods where higher percentages of children come from low-income households. Children in the study also were more likely to be English learners.

- Measurement tools available in this area are limited. There are no standardized preschool mathematics measures with valid subtests for particular skills (counting, patterns, subitizing, and so on). The REMA was the best possible standard measure available, but measures a broader set of skills than the curriculum supplement covers and does not have sub-skill scales. The measure has been shown to be valid and reliable with children from lower-income households, like the ones recruited for this study.

- While the available validity and reliability data for the SBA assessment is sound and the development of the measure was conducted according to the highest research standards, the amount of psychometric data available on the measure is limited when compared to standardized measures.

- Teacher findings are based on data that were gathered through teachers' own replies to survey questions. Researchers did not independently measure teacher knowledge or attitudes.

- While implementation logs (completed by teachers and coaches) and fidelity and quality observations (conducted by researchers) provide some insight into the quality and quantity of opportunities to learn mathematics in study classrooms, observations were not conducted in all classrooms and there is no way to independently verify teacher reports of the frequency and focus of mathematics lessons.

- Given the length of the intervention—10 weeks—and the time required by teachers to become proficient using new educational technologies in their classrooms, long-range impacts on teacher practice and the associated impacts on children's skills and knowledge are unknown.

Conclusion and Future Research

This CPB-PBS *Ready To Learn* study provides evidence that a curricular supplement that uses a transmedia approach can support young children's mathematical skills as well as teachers' confidence and comfort with early mathematics concepts and teaching with technology. While teachers whose classrooms received an infusion of digital resources (Technology & Media condition) integrated new technology tools and media resources into the mathematics lessons at quite high rates, and teachers whose classrooms were unaltered by the study (Business as Usual condition) spent considerable time and effort supporting children in learning basic mathematics skills, it was only the children in the PBS KIDS Transmedia Math Supplement group who improved significantly in their mathematics skills as a result of their participation. That a 10-week intervention could support measurable mathematics learning and teachers' professional development is noteworthy. Though increasing, the number of research studies and curriculum initiatives in the field of preschool mathematics is limited compared to other areas of preschool learning, such as early literacy (e.g., Opening the World of Learning [OWL]) (Wilson, Morse, & Dickinson, 2009) and social and emotional development (e.g., Second Step) (Diamond, Justice, Siegler, & Snyder, 2013; Frey, Hirschstein, & Guzzo, 2000). Partial-year curriculum supplements, like the one studied in this randomized controlled trial, are rare both in their existence and as a focus of research.

While findings from this study may offer promise to those seeking to improve learning opportunities available to young children from traditionally under-resourced communities, the study is likely to be more useful when considered together with the research team's 2009 *Ready To Learn* study on digital media and young children's emergent literacy skills (Penuel et al., 2009). Not only did that earlier study also yield positive findings pointing to digital media's effectiveness, the pair of studies shares many of the same explanations for why the findings are what they are:

- ***Ongoing professional support is crucial for teachers and, consequently, for the children in their classrooms.*** While much attention has been focused on the promising role of technology for learning, and on the importance of early learning, the reality in the majority of early learning settings is little or no reliable access to digital tools and little or no support or training for using technology. Both *Ready To Learn* summative studies emphasized the importance of teacher professional development and support as a central component of any effective intervention. This emphasis grew from an examination of the literature suggesting that educators require training to use and integrate new tools into their instructional practice, and also resulted from the pilot studies that preceded each of the full studies. The types of support that teachers received over the course of the 10-week study period, therefore, were consequential, as teachers received both technical as well as pedagogical guidance. Coaches in PBS KIDS Transmedia Math Supplement classrooms provided feedback that was targeted toward helping teachers enact technology-centered and media-rich mathematics lessons intentionally designed to help children acquire, practice, and build on specific quantitative thinking skills. The findings suggest that, when teachers are prepared with the knowledge and experience needed to mediate children's learning with technology, children will be able to make use of the learning opportunities available through engagement with digital media.

- ***A sharp curricular focus adds potency to a common approach to technology integration, which tends toward the general and aspirational.*** Both *Ready To Learn* studies used a Teacher's Guide that introduced and provided context for the integration of digital and non-digital activities. The full complement of activities provided children with exposure to and practice with a specific set of skills. Researchers designed the teacher guides to build on existing research about developmental trajectories for young children in mathematics and literacy, and also tested and modified the guides prior to final implementation. The guides served two key purposes: First, they laid out a concrete approach for integrating digital tools into ongoing instruction (both in terms of structure and also content), and second, they included pre-selected and sequenced digital media. Conversely, without the benefit of a sequenced set of activities, Technology & Media teachers were responsible not only for integrating new technology platforms into their classroom instruction but also for undertaking the significant design work of matching resources to planned mathematics activities, identifying resources, and creating larger arcs of lessons to ensure children had the repeated, linked opportunities to learn target skills. Seen in this way, it is perhaps not surprising that these teachers and the children they taught did not experience the same changes in skill and attitude toward mathematics or technology as did PBS KIDS Transmedia Math Supplement teachers and children.

- ***Teachers are the ones best able to mediate young children's media engagement, leading to their learning.*** Even with high-quality public media mathematics or literacy resources, the presence of an adult whose explicit goal is to support learning is required. Teachers who orchestrate children's experiences with media provide critical feedback, encouragement, direction, and other guidance, and are well positioned to help children interact with one another in ways that support learning beyond what solo or unmediated experiences with digital and non-digital resources might provide.

- ***Digital transmedia can advance content-area learning for young children, and may be of greatest value for those children who are most in need of academic support.*** Given the increasing recognition of the importance of early learning as a foundation for later academic success, the role that digital tools might play in improving learning outcomes for children who are academically at-risk is substantial. Most promising may be the studies' findings that when media and technology are integrated into preschool settings in thoughtful and deliberate ways, they have the potential to help close the persistent achievement gap between children living in traditionally under-resourced communities who composed the sample for these experiments and their more advantaged peers. In the 2009 literacy study, children who scored lowest on pre-tests of early literacy skills were shown to have the largest gains at post-test. While additional research is needed, the promising, though non-significant, interaction between lower pretest scores and greater gains in the current study could mean that children in the bottom quartile who began the study with less-developed mathematics skills than their classmates (as measured by study assessments) benefitted most. These children's early transmedia mathematics experiences, and their teachers' understanding of how to bring about these experiences, seem to be well aligned to some of the very target skills they had not yet developed.

- ***Recognizing teachers as the professionals they are is both a starting place and a commitment that must be sustained.*** An important component of both studies, and perhaps a reason for the high rate of response and low attrition, is the research team's focus on maintaining a relationship with sites that is professional and respectful of the time and effort required to participate in a research study spanning several months. Researchers provided information to all participants about the role of a randomized controlled trial in the context of an education study, the importance of having a Business as Usual condition and what this means for the study findings, the role of professional development and the provision of this for all teachers, even those in the Business as Usual condition (to be provided after the study was over), and the provision of stipends and a recognition of the time teachers spent on completing paperwork, logs, and surveys throughout the study period. One outcome from this is that sites are willing to work with the researcher teams' organizations on future studies. Another is the ongoing use of study materials in many sites, with teachers who participated in different study conditions using the intervention materials provided to all sites after completion of the study. When teachers see that a new intervention, tool, or curriculum is developed by professionals who are respectful of the challenges faced and the needs and demands created by a new intervention, teachers are more likely to make the changes necessary to embrace and implement the intervention rather than dismiss it as another short-lived initiative. Researchers have had the opportunity to see teachers continuing to use 2009 *Ready To Learn* study materials, and also have observed use of the 2013 *Ready To Learn* study materials by non-intervention classrooms once the study was over.

Finally, the lack of significant differences in children's self-regulation skills, either for better or worse, is important to note. Many in the early learning community have held the belief that time spent with media and technology resources, no matter how well designed the resources may be or how well integrated into established preschool routines, can have a negative effect on children's attention and executive functioning. Others have pressed the case that technology and media experiences can have a beneficial effect on self-regulation because they recruit and sustain children's attention, often for extended periods of time. This study's null finding provides no evidence for either side in this disagreement.

Future Research

The study's implementation and findings point to several directions for ongoing research in the area of early learning.

- ***Early learning math assessments.*** As the field of early mathematics assessment matures, two necessary advances would be the creation and validation of assessments that include subscales for individual skills, and that these and other assessment instruments are made valid and reliable for children living in under-resourced communities and English learners. Access to a broader range of reliable assessment options for early learning would increase the likelihood that the impact and value of future mathematics interventions could be measured with more accuracy.

- ***Professional learning.*** The role of coaching and the provision of professional development in early learning environments is also an area that could benefit from greater study to determine which approaches to professional development are most effective for teachers serving children who are at-risk academically. For example, little work has addressed how long coaching must last to provide long-term impact on teacher practice, or the relative benefit of training sessions that take place before or during implementation.

- ***Digital media's alignment with a range of skills.*** Another area where more research can provide greater insight into early learning are the roles that both video and digital games are uniquely suited to play. This work should focus on how such resources may support children's developing understanding of key concepts within mathematics and other content areas—both those concepts and skills commonly taught in isolation as well as others important to fuller learning progressions. Research in this area could include both how children can be supported with still-emerging technologies and also how teachers can be supported to use these tools, perhaps expanding their pedagogical and content knowledge.

Work in these areas will greatly enhance future research studies and will inform the design and development of programs that educators can use, and from which children can benefit.

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Appendices

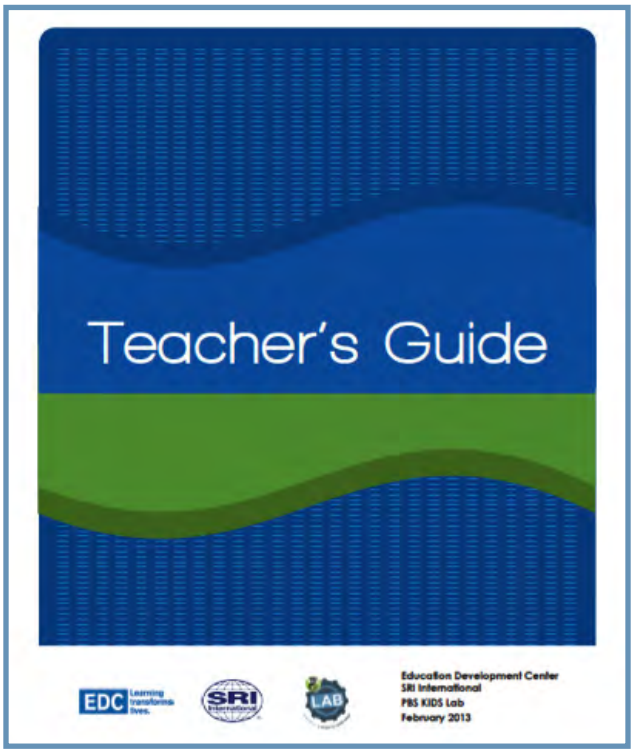
Appendix A: Site Implementation Characteristics

Site Implementation Characteristics	PBS KIDS Transmedia Math Supplement	Technology & Media	Business as Usual
Interactive Whiteboard, 3 Chromebook laptops, Wireless Internet	✓	✓	
Printed 10-week Math Curriculum 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 Curriculum Supplement	✓		
Professional development on math after study implementation			✓
Hands-on materials to enact 10-week PBS KIDS Math Curriculum 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 Math Curriculum Supplement	✓		
Back-end data collection of browsing history and use of Google Analytics	✓	✓	
Observation focused on fidelity of PBS KIDS Math Curriculum Supplement	✓		
Observation protocol focused on mathematics instruction	✓	✓	✓
Weekly logs for teachers to reflect on their experiences	✓	✓	✓
Weekly logs for coaches to reflect on their experiences	✓	✓	
Teacher survey including beliefs and attitudes about math and technology	✓	✓	✓
Child assessments before and after study implementation	✓	✓	✓
Parent survey focused on math instruction and media and technology use at home	✓	✓	✓

Appendix B: Digital Assets Included in the PBS KIDS Transmedia Math Supplement

Asset	Video	Transmedia Games
Sid the Science Kid	*Dirt on Dirt*	*Crystals Rule*
		Vegetable Patterns
		Vegetable Harvest
Curious George	*Train Master*	*Ribbit*
	Shutter Monkey	*Count with Allie*
	Rocket Ride	*Apple Picking*
	Zero to Donuts	*Bug Catcher*
	Bunny Hunt	*Flower Garden*
		Blast Off
		Bubble Pop
		Meatball Launcher
		Hide and Seek
		Bunny Ride
		Fair Shares
The Cat in the Hat	*Let's Go Fly a Kite*	*Huff-Puff-a-Tron*
	Termite Towers	*Sketch-a-Mite*
		The Great Shape Race
Dinosaur Train		*Buddy's Gem Hunt*

Appendix C: Teacher's Guide Included in the PBS KIDS Transmedia Math Supplement

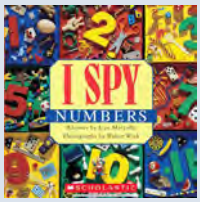
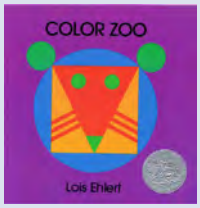


Appendix D: Non Digital Materials Included in the PBS KIDS Transmedia Math Supplement

Materials	Units Per Class
Books (7 different titles)	*1 Book Per Title*
Math Detective Journals	*20 Journals*
Classroom Number Lines (-20 – 100)	*1 Number Line*
Crayons	*4 Boxes*
Dry Erase Boards with Markers	*4 Boards with 1 marker each*
Dry Erase Markers	*1 Package*
Dry Erase Erasers	*2 Erasers*
Personal Number Line (0-30)	*6 Number Lines*
Pipe Cleaners	*3 Packages*
Shape Stickers	*50 Sheets*
Foam Shapes	*2 Packages*
Assorted Plastic Fruit	*2 Containers*
Large Foam Dominoes	*1 Package*
Unifix Cubes	*1 Box*
Construction Paper	*2 Packages*
Large Foam Dice (1 package contains 2 dice)	*1 Package*
Hand Pointer	*1 Pointer*
Mouse Paw Stickers	*1 Sheet*
Clear Plastic Storage Bags (Gallon)	*1 Box*
Clear Plastic Storage Bags (Quart)	*1 Box*
Oops! Board 0-10	*4 Boards*
Oops! Number Tiles 0-10	*4 Sets of Tiles*
NUMBO Boards 0-5 (1 package contains 6 boards)	*1 Package*
NUMBO Cards 0-5 (1 package contains 6 cards)	*3 Packages*
NUMBO Boards 1-20 (1 package contains 6 boards)	*1 Package*
NUMBO Cards 1-20 (1 package contains 20 cards)	*3 Packages*
Large Shape Cards (1 package contains 9 shapes)	*2 Packages*
Simple Shape Concentration Cards (1 package contains 8 cards)	*4 Packages*
Fruit Pattern Cards (AB/ABB/ABC) (1 package contains 12 cards)	*2 Packages*

Materials	Units Per Class
Shape Sticker Pattern Cards (AB/ABB/ABC) (1 package contains 12 cards)	*2 Packages*
Unifix Cube Pattern Cards (AB/ABB/ABC) (1 package contains 12 cards)	*2 Packages*
Foam Shape Pattern Cards (AB/ABB/ABC) (1 package contains 12 cards)	*2 Packages*
Number Tree Board (1 package contains 6 boards)	*2 Package*
Fruit to Number Concentration Card (1 package contains 20 cards)	*4 Packages*
Number Act Out Cards (1-5) (1 package contains 5 cards)	*4 Packages*
Shape Match (1 package contains 12 sticks)	*4 Packages*
Shutter Monkey Cards (1 package contains 4 cards)	*2 Packages*
Body Shape Cards (1 package contains 4 cards)	*2 Packages*

Appendix E: Books Included in the PBS KIDS Transmedia Math Supplement

Cover	Title	Author/ Illustrator	Cover	Title	Author/ Illustrator
	*I Spy Numbers*	Jean Marzollo		*Ten, Nine, Eight*	Molly Bang
	*Round is a Mooncake: A Book of Shapes*	Roseann Thong Grace Lin		*Zero*	Kathryn Otoshi
	*Busy Bugs: A Book About Patterns*	Jayne Harvey Bernard Adnet		*Pattern Fish*	Trudy Harris Anne Canevari Green
	*Color Zoo*	Lois Ehlert			

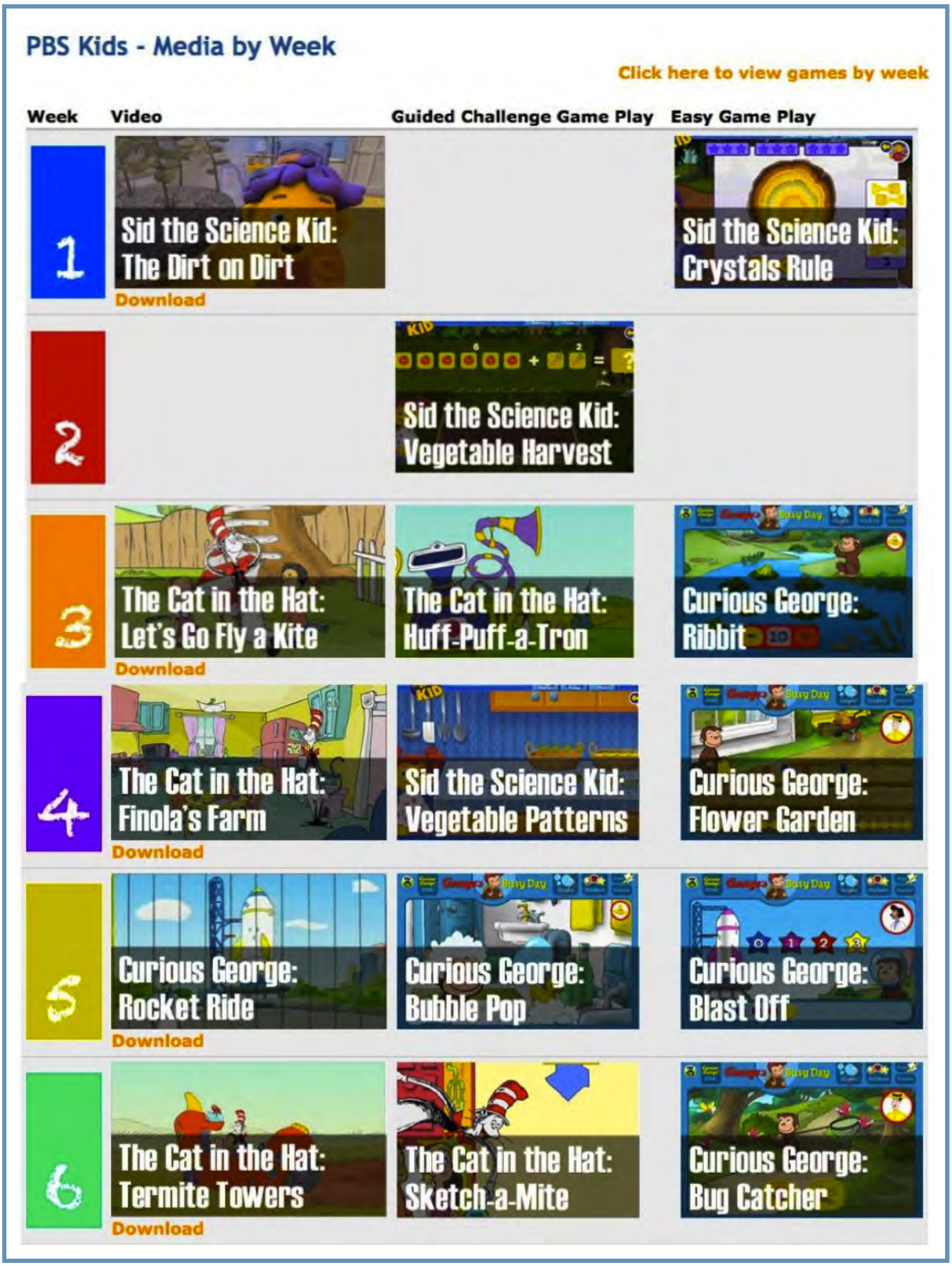
Appendix F: Images of Interactive Whiteboard and Laptops Included in the PBS KIDS Transmedia Math Supplement

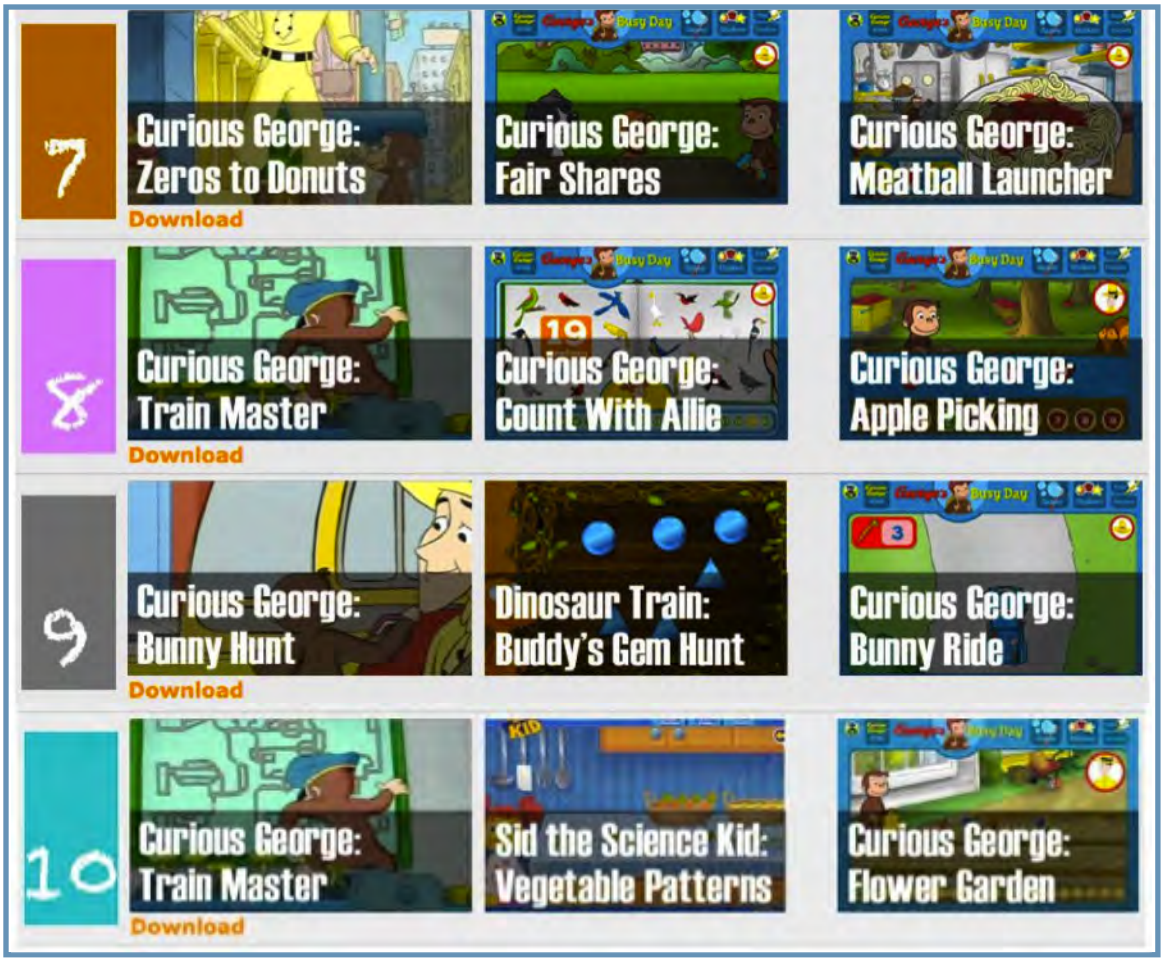
Figure F1. The interactive white board installed on an adjustable-height cart with storage bins for study materials

Figure F2. Laptops set up for use by children in a classroom

Figure F3. A child interacting with a PBS KIDS game on an interactive whiteboard

Appendix G: CMS Site that Supported the PBS KIDS Transmedia Math Supplement




7
Curious George: Zeros to Donuts
Download
Curious George: Fair Shares
Curious George: Meatball Launcher
8
Curious George: Train Master
Download
Curious George: Count With Allie
Curious George: Apple Picking
9
Curious George: Bunny Hunt
Download
Dinosaur Train: Buddy's Gem Hunt
Curious George: Bunny Ride
10
Curious George: Train Master
Download
Sid the Science Kid: Vegetable Patterns
Curious George: Flower Garden

Appendix H: Professional Development Model Included in the PBS KIDS Transmedia Math Supplement

Teachers in the PBS KIDS Transmedia Math Supplement group received:

- Seven hours of professional development over a two-day period – either off-site in a large group (by study staff) or on-site in small groups or one-on-one settings (by coaches) – prior to enacting the first week of the curriculum supplement.

Professional Development experiences covered:

- The target math skills contained in the PBS KIDS Transmedia Math Supplement (Counting & Subitizing; Identifying Numerals; Recognizing, Composing, and Representing Shapes; and Patterning)
- Activities that comprised the ten-week PBS KIDS Transmedia Math Supplement
- Instructional strategies for using the PBS KIDS Transmedia Math Supplement activities to support children's math learning
- The Teacher's Guide that detailed the 10-week PBS KIDS Transmedia Math Supplement
- The media and technology resources, and the principles behind how they were integrated into early math teaching and learning activities
- What they could expect from their instructional coach as well as what their coach would expect of them.

Appendix I: Detailed Analysis

Attrition Analysis

The WWC Standard version 3.0 (draft) includes a procedure and table of thresholds for analyzing attrition in cluster randomized designs. First, attrition is assessed at the cluster level (for this study, classrooms). Next, using the sample of classrooms whose data may be used in the impact model, the individual cases are analyzed for attrition.

The results of this study's attrition analysis appear below. Attrition among classrooms was generally low overall (3%, or 3 out of 86 classrooms). The highest differential attrition percentage at the classroom level was 7% (PBS KIDS Transmedia Math Supplement vs. Business as Usual); this is largely due to the loss of two classrooms from the BAU condition and no classrooms from the PBS KIDS Transmedia Math Supplement condition. The research team has determined that this classroom attrition was due to a fire in the corresponding Center; participation in the study was discontinued for this Center.

At the student level, conditional on classrooms being in the final sample, overall attrition ranges from 13% to 22%. The level of attrition was higher for HTKS, likely due to the fact that more children expressed wanting to discontinue participation in this assessment. Differential attrition among conditions was quite low—analyzed without reference to clustering[4], the differential attrition rates of 2% or 3% would qualify this analysis as meeting WWC group design standards "without reservations."

The attrition rates of 13% to 22% do trigger a requirement under WWC standards to analyze the data for baseline equivalence at pre-test. The following section summarizes that analysis.

Baseline Equivalence Analysis

Using the set of complete cases for each measure, the research team computed descriptive statistics for all three pre-test measures by condition. The team also computed pooled standard deviation across condition, which enabled the computation of an effect size statistic for contrasts between both the PBS KIDS Transmedia Math Supplement and Technology & Media conditions and the Business as Usual condition. The results of this contrast analysis are shown in Table I2. The baseline differences for the PBS KIDS Transmedia Math Supplement vs. Business As Usual contrast ranged in absolute value from .02 to .11. For the Technology & Media vs. Business As Usual conditions these ranged from .04 to .15.

4 The WWC Draft Standards (v3) suggest that differential attrition be analyzed at both the cluster and individual level. A differential attrition rate at the classroom level of 7% would qualify this report as meeting WWC standards "with reservations." However, these draft standards are still under review and are subject to change. The current analysis of study quality is based on the currently active WWC Standards (v2.1)

Table I1. Table of sample sizes, attrition rates, and differential attrition rates, by condition and outcome measure

	HTKS				REMA				SBA			
	N	N data	Att %	vs. BAU	N	N data	Att%	vs. BAU	N	N data	Att %	vs. BAU
Classroom												
PBS KIDS Transmedia Math Supplement	27	27	0%	-7%	27	27	0%	-7%	27	27	0%	-7%
Tech & Media	30	29	3%	-4%	30	29	3%	-4%	30	29	3%	-4%
BAU	29	27	7%		29	27	7%		29	27	7%	
Combined	86	83	3%		86	83	3%		86	83	3%	
Student												
PBS KIDS Transmedia Math Supplement	307	239	22%	-2%	307	257	16%	-3%	307	264	14%	0%
Tech & Media	308	246	20%	-4%	308	257	17%	-3%	308	270	12%	-2%
BAU	309	233	25%		309	248	20%		309	266	14%	
Combined	924	718	22%		924	762	18%		924	800	13%	

Table I2. Standardized mean baseline differences, by treatment contrast and outcome

Contrast	EMA	HTKS	SBA
PBS KIDS Transmedia Math Supplement vs. Business As Usual	-0.11	0.09	0.02
Technology & Media vs. Business As Usual	-0.04	0.15	0.12

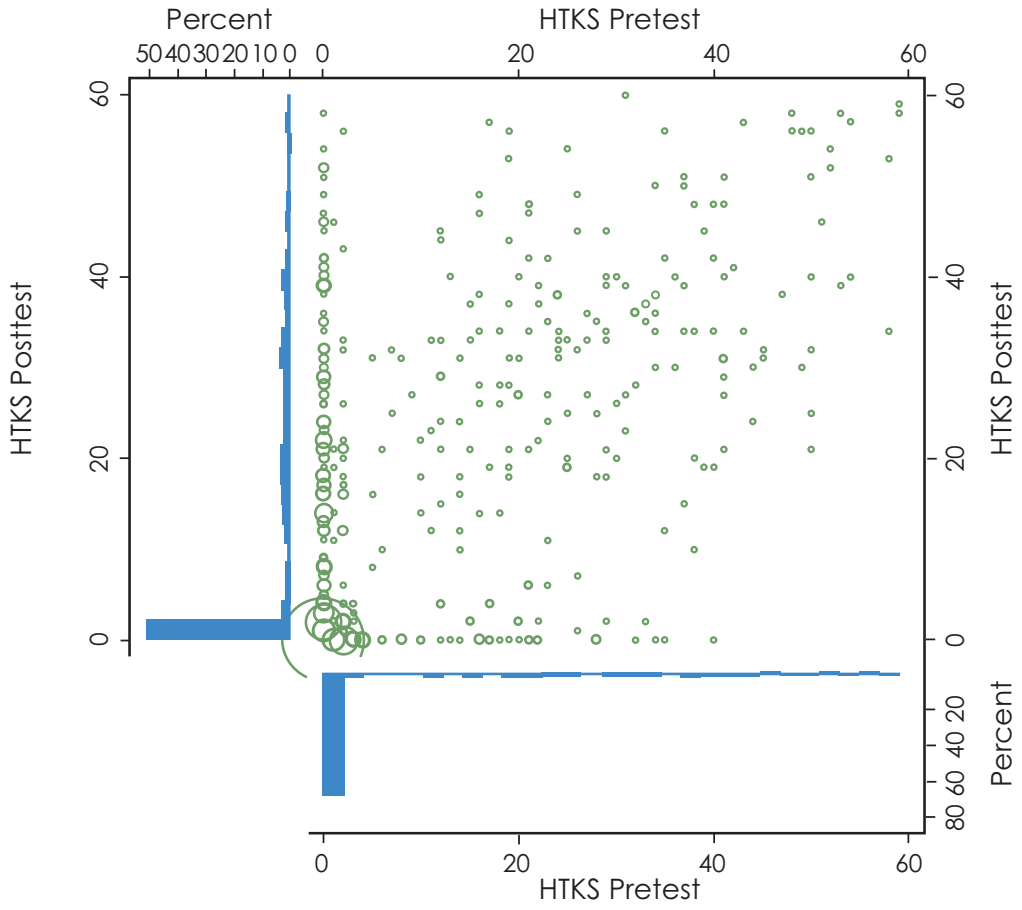
The WWC Standards specify that baseline equivalence difference greater than .05 standard deviations but less than .25 standard deviations call for explicit adjustment for these differences to be included in the analytic models. While two of the six contrasts fall under the .05 threshold (and according to the WWC standards do not require adjustment for baseline differences), the research team consistently included adjustment for baseline differences in all of the analytic models. Inclusion of baseline measures at the student and group levels substantially boosts statistical power, and had been the research team's intention from the initial design of this evaluation.

Two anomalies were detected that warranted further investigation: a preponderance of "0" scores on the HTKS assessment, and heteroskedastic residuals for both the HTKS and SBA assessments.

HTKS Anomalies

In examining the HTKS assessment data, the research team discovered that 57% of the pre-test scores and 42% of post-test scores are zero in the analytic sample. This results in a very skewed score distribution, and calls into question the linear relationship between post-test and pre-test measures. The distribution of scores and their relationship are illustrated in Figure I1.

Figure I1. Distribution of HTKS pre-test and post-test scores



An analysis fitting the squared residual of the HTKS analytic model against the pre-test predictor indicates inflated residual variance and a non-linearity for data where the pre-test score is less than 4. Because the validity of the model does not critically depend upon a true linear relationship between pre-test and post-test, researchers ignored the non-linearity for small pre-test values. However, the research team does address the heteroskedastic residuals in the next section.

Heteroskedastic Residuals

Researchers detected heteroskedastic residual variance in models fitting the SBA and HTKS scores; models fitting the REMA displayed no heteroskedasticity. Failure to adjust for non-constant residual variance could lead to a biased estimation of both model parameters and standard errors.

Several solutions to this problem exist. In order to preserve the interpretation of the model parameters as test scores, the research team has chosen not to mathematically transform the outcome measure into a result that, while producing homoscedastic error variance, would be essentially uninterpretable as an impact model. Rather, researchers take advantage of Stata's ability to specify HLM models with heteroskedastic error variance. For the HTKS models, researchers specify two levels of residual variance (one for cases with pre-test score less than 4, one for all other cases). For the SBA models, researchers specify four levels of residual variance, based on the quartile of the pre-test score.

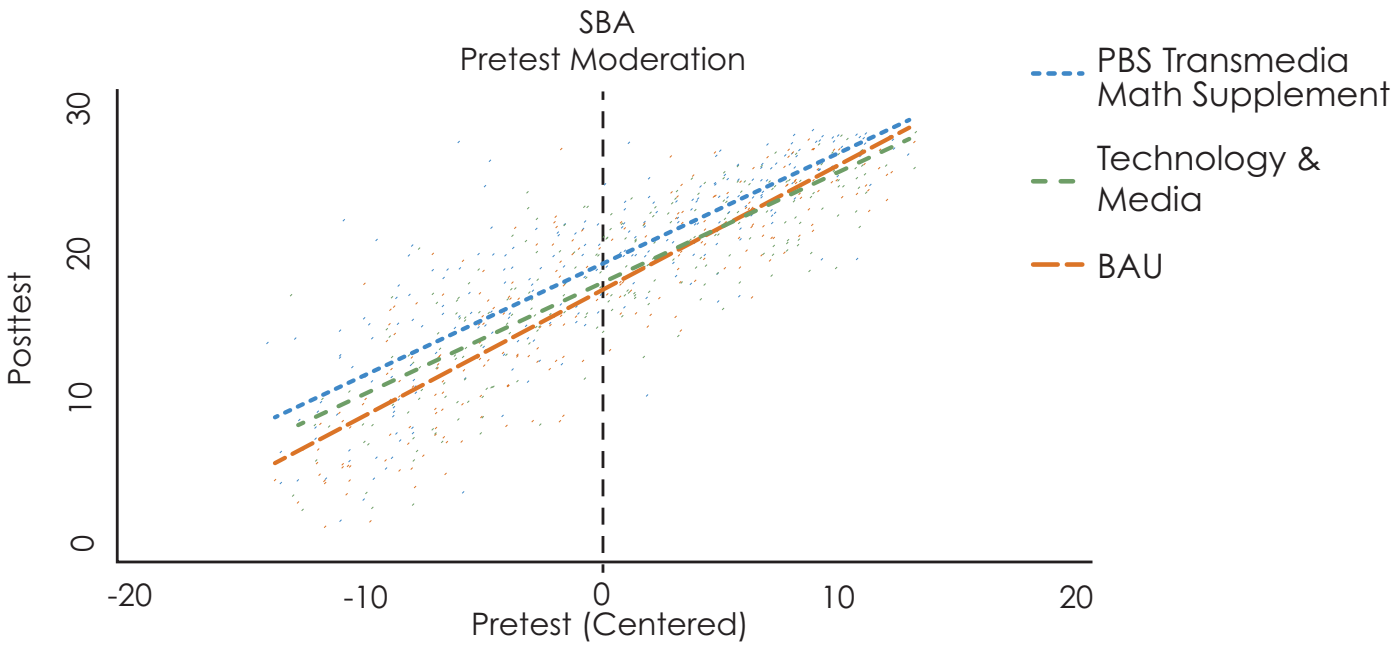
Table I3. Summary of PBS KIDS Transmedia Math Supplement moderation model estimates, treatment by pre-test score

Model and Parameter	Coefficient	Std. Error	P	Multiple Comparison Test*
HTKS				
PBS KIDS Transmedia Math Supplement vs BAU	-0.25	1.444	0.864	
Tech & Media vs BAU	-0.91	1.469	0.535	
PBS KIDS Transmedia Math Supplement x Pretest	-0.12	0.099	0.230	---
Tech & Media x Pretest	0.03	0.094	0.725	---
REMA				
PBS KIDS Transmedia Math Supplement vs BAU	1.11	0.590	0.061	
Tech & Media vs BAU	-0.01	0.587	0.992	
PBS KIDS Transmedia Math Supplement x Pretest	0.10	0.069	0.131	---
Tech & Media x Pretest	0.00	0.072	0.979	---
SBA				
PBS KIDS Transmedia Math Supplement vs BAU	1.72	0.321	0.000	
Tech & Media vs BAU	0.40	0.334	0.237	
PBS KIDS Transmedia Math Supplement x Pretest	-0.07	0.039	0.057	---
Tech & Media x Pretest	-0.10	0.041	0.019	---

*Note: thresholds for statistical significance of moderator coefficients adjusted for six comparisons using the Benjamini-Hochberg False Discover Rate procedure

Figure I2 displays a color-coded scatter plot of the SBA post-test scores against centered pre-test scores, with approximate lines of best fit[5] drawn in for each of the three conditions. The slope of the BAU line (green) is somewhat steeper than the slopes of either the PBS KIDS Transmedia Math Supplement line (red) or Technology & Media line (blue). The gap between the PBS KIDS Transmedia Math Supplement/ Technology & Media lines and the BAU line grows smaller as the pre-test scores increase; this is a graphical interpretation of a negative interaction coefficient shown in Table I3. In other words, the PBS KIDS Transmedia Math Supplement impact appears greater for students with lower pre-test scores, and smaller for students with higher pre-test scores.

Figure I2. Illustration of pre-test moderation in SBA impact models



5 These lines are not precisely the same as the model-estimated intercepts and slopes of the centered pre-test scores, due to inclusion of a group-level pre-test score in the original model. These graphs, however, serve to illustrate the moderation results shown in table I3.

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