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Supplementing literacy instruction with a media-rich intervention: Results of a randomized controlled trial☆

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ABSTRACT

This study investigates whether a curriculum supplement organized as a sequence of teacher-led literacy activities using digital content from public educational television programs can improve early literacy outcomes of low-income preschoolers. The study sample was 436 children in 80 preschool classrooms in California and New York. Preschool teachers were randomly assigned to implement either a 10-week media-rich early literacy intervention that employed clips from *Sesame Street*, *Between the Lions*, and *SuperWhy!* or to a comparison condition. The media-rich literacy supplement had positive impacts ($+0.20 \leq d \leq +0.55$) on children's ability to recognize letters, sounds of letters and initial sounds of words, and children's concepts of story and print. The study findings show the potential for incorporating literacy content from public media programming into curriculum supplements supported by professional development to impact early literacy outcomes of low-income children.

Young children from low-income families are far less likely to enter kindergarten with foundational early literacy skills than are their more economically advantaged peers, putting them at high risk for later reading difficulties (Snow, Burns, & Griffin, 1998). Addressing this gap early is critical, as longitudinal analyses show that elementary schools do not close the reading achievement gaps between low- and middle-income children present at kindergarten entry (Alexander, Entwisle, & Olson, 2007). For this reason, many intervention efforts have focused on promoting early literacy skills for this disadvantaged group of children (Chatterji, 2006; Juel, Griffith, & Gough, 1986; West, Denton, & Reaney, 2000).

Content from children's public television represents a potentially valuable resource for developing early literacy interventions, because studies examining the impact of public educational television viewing consistently show positive effects for a wide range of school-related outcomes, including literacy (for reviews, see Fisch, 2004b; Thakkar, Garrison, & Christakis, 2006). Two early experimental studies conducted by the Educational Testing Service in the first and second years of production for *Sesame Street* (Ball & Bogatz, 1970; Bogatz & Ball, 1971) found that children encouraged to watch the show made greater gains in letter knowledge relative to students in a control group. Since those first impact studies, researchers have found associations between preschoolers' viewing of educational television and letter-sound awareness (Linebarger, Kosanic, Greenwood, & Doku, 2004), phonemic awareness (Linebarger et al., 2004), expressive language (Linebarger & Walker, 2005), and vocabulary (Linebarger et al., 2004; Linebarger & Walker, 2005; Rice, Huston, Truglio, & Wright, 1990; Rice & Woodsmall, 1988) in early childhood, as well as book reading in adolescence (Anderson, Huston, Schmitt, Linebarger, & Wright, 2001).

At present, few children are exposed to public television programs' content in early childhood education settings (Wartella, Schomburg, Lauricella, Robb, & Flynn, 2009). In part, students may have limited exposure because many preschool teachers object to the use of media in preschool settings (Bayhan, Olgun, & Yelland, 2002) and because producers have not packaged the materials in a way that could be readily integrated into classroom instruction. In recent years, however, with support from the U.S. Department of Education's *Ready to Learn* program, CPB and the Public Broadcasting Service (PBS) have sought to identify strategies for integrating media content from its educational television programs into curriculum materials intended for use in preschools. The materials that have been developed are targeted to low-income children and

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integrate video clips, computer games associated with particular programs, and activities that rely on interactions with traditional print resources. As part of this effort to develop materials for use in preschools, CPB and PBS have invested in research studies to assess the impact of such materials on young children's literacy outcomes.

The current study describes the development and evaluation of a media-rich curriculum supplement developed as part of *Ready to Learn*. The curriculum supplement incorporated activities in which teachers used digital video, online games, and hands-on activities to provide children with a motivating way to gain letter knowledge, knowledge of letter sounds and initial word sounds, and an understanding of concepts of print. These media-rich activities employed digital content from three public television programs that aim to support literacy learning among preschool-aged children: *Sesame Street*, *Between the Lions*, and *SuperWhy!* Integral to the design of the supplement was guidance from coaches, who modeled teacher-led activities and observed preschool teachers implementing the supplement. As part of the evaluation of the supplement, we conducted a cluster randomized trial to estimate the impacts on early literacy skills with 436 children in 80 preschool classrooms.

In this paper, we provide a theoretical rationale for this work, describe the curriculum supplement developed, and report on the results of an efficacy study conducted to address the following main research question: Can integrating public media content from different platforms into curriculum materials improve literacy outcomes for young children?

1. Background to the study

Though professional organizations have endorsed the appropriate use of media to support learning in early childhood (e.g., National Association for the Education of Young Children, 1996), many have expressed concern about their integration into preschools. Many educators believe media and technology interfere with social interaction, which is critical to early learning (Bayhan et al., 2002). With this particular concern in mind, we review theoretical and empirical support that suggests integrating content from educational programming does have potential to foster children's early literacy learning in ways that can be augmented by interactions with social partners. We also review below the conditions that may be necessary to achieve this aim.

2. Theoretical and empirical support from studies of educational television viewing

One reason why it may be valuable to integrate content from public educational television programs into school settings is that producers employ strategies for teaching skills that are analogous to the strategies that are supported by research on effective literacy instruction (National Institute for Literacy, 2008). A recent review of six literacy programs broadcast on PBS (Linebarger & Piotrowski, 2010) found numerous instances where children were prompted to engage in comprehension monitoring of the main storyline, and where characters on screen give voice to positive attitudes toward print and print literacy. The strategies they documented, such as activating prior knowledge, reviewing content after it is presented and modeling positive attitudes toward print, are all strategies that other researchers have found can help promote comprehension and increase interest in literacy learning (Michel & Roebers, 2008; Rowe, 1991). Another common strategy producers employ is to invite children to practice reading letters, phonemes, and words on screen print, where the reading is supported with both visual and verbal cues (Linebarger, 2006). Producers link these reading activities directly to the main characters and events in the story, making the practice with skills more meaningful and engaging to children (Fisch, 2004b).

A second reason why content from children's educational television may benefit children's literacy skills is that producers only select for broadcast those program segments that best capture and sustain children's attention, on the presumption that attention is a critical prerequisite to learning and is especially critical to developing a positive disposition toward literacy (Fisch, 2004b). Broadcast segments often allow and invite children to develop parasocial relationships with characters on screen that extend beyond the program. When children identify with a character, emotional investment in the program increases, and consequently, so does the likelihood of learning educational content (Fisch, 2004a; Richert, Robb, & Smith, 2011). When the character invites interaction with the child as many contemporary programs do, the child may also be more likely to interact with the character, producing greater comprehension of content (Calvert, Strong, Jacobs, & Conger, 2007). Repeated viewings, when children have developed parasocial relationships with characters, instead of leading to boredom, often lead to successful engagement with the content (Anderson et al., 2000; Jennings, Hooker, & Linebarger, 2009). The value of sustaining children's attention over multiple exposures to the same literacy content through repeated viewings is of potential benefit to literacy learning. When children are exposed to activities that teach basic skills through traditional techniques of memorization, children may become bored and take much longer to learn these skills (National Reading Panel, 2000).

A third reason why children might benefit from exposure to public educational television content in formal educational settings is that preschools are settings where there are many social partners with whom children can engage with media, and studies show that interacting with social partners while viewing can augment learning. Caregivers who watch television programs alongside children often engage in many verbal interactions with them that, intentionally or incidentally, direct their attention in ways that facilitate language development, including naming and identifying objects, repeating new words, asking questions, and relating the content to children's own experience (Lemish & Rice, 1986). In addition, there is direct evidence that viewings supported by adult guides can augment learning of new letters, letter-sounds, phonemes, and words from joint engagement with media, specifically by inviting and scaffolding children to make connections between what is depicted in digital media and real life (Jennings et al., 2009; Reiser, Tessmer, & Phelps, 1984; Reiser, Williamson, & Suzuki, 1988). Taken together, these findings suggest that interacting with public educational television content in a preschool setting can help children develop early literacy skills, especially when adult partners have guidance as to how to instructionally mediate viewing.

3. Empirical support for integration of public media content into school settings

Notably, nearly all of the positive findings about the impacts of educational television come from studies conducted in laboratory settings or in children's homes, and not from school settings. However, there is a limited body of evidence that literacy curriculum materials that integrate opportunities for joint engagement with digital media can have a positive impact on preschool children's literacy outcomes. One of the first such studies focused on African American and Native American children living in rural Mississippi (Prince, Grace, Linebarger, Atkinson, & Huffman, 2002). Researchers in that study provided early childhood educators in the intervention condition with a comprehensive curriculum that included whole episodes of the children's educational television program *Between the Lions*, which focuses on phonics instruction,

books related to themes covered during the program, and interactive literacy activities. Teachers participated in intensive, daylong workshops to familiarize themselves with the resources and learn strategies for using them to supplement the school's existing literacy curricula. During the school year, preschool, kindergarten, and first grade students in the treatment group viewed at least two *Between the Lions* episodes, read a book that builds upon the focal skills of the episode (e.g., rhyming), and then participated in a hands-on activity that reinforced the skill or theme stressed in the episode. The researchers documented positive effects of participating in the intervention on letter name knowledge and letter-sound correspondence for African American children living in Mississippi Delta communities, and positive effects on understanding of concepts of print for children living on the Choctaw Native American reservation.

Two studies from the *Ready to Learn* Initiative, of which the present study is part, found similar positive effects of integrating public media content into curricular materials implemented in preschool settings. In one study, Linebarger (2009) evaluated the impacts of a program that integrated content from the program *Between the Lions* into a curriculum supplement and provided mentoring to guide teachers' use. She found the program had a positive impact on both teacher practice and children's early literacy outcomes. As part of another study, Neuman et al. (Neuman, Newman, & Dwyer, 2010) conducted a randomized controlled trial of a vocabulary curriculum that integrated video clips from the program *Sesame Street*; they found positive impacts on target vocabulary.

A limitation of prior studies focused on integrating educational television content into school settings is that none has been conducted in a large sample of classrooms in the field. Large, randomized controlled trials are important tests of curriculum supplements that target preschoolers and incorporate digital media, because variation in implementation is likely to be higher and may be associated with greater variability in estimates of impacts on students (Pasnik, Strother, Schindel, Penuel, & Llorente, 2007). Conversely, large randomized controlled trials can provide preliminary evidence of the robustness of curricular materials, that is, the extent to which positive impacts are possible to achieve across a wide variety of settings (Roschelle, Tatar, Shechtman, & Knudsen, 2008).

In addition, when implemented with a large, diverse sample, in a field trial is possible to analyze factors that may moderate potential treatment effects. In early childhood settings, children most at risk may interpret and respond to teaching and curriculum activities in ways that shape their experience of classrooms (Hamre & Pianta, 2005). Studies of the impacts of educational television programming indicate there can be variability in effects of viewing linked to both parent income and age (Thakkar et al., 2006; Wright et al., 2001).

4. Conditions for effective integration of digital media into preschool literacy materials

Effective integration of digital content from programs such as *Between the Lions* and *Sesame Street* requires an appreciation of preschool settings, as well as the needs and skills of teachers in those settings. Conditions for effective integration include openness on the part of leaders and teachers in a preschool to the use of media and access to it, ensuring intensity of exposure to critical early literacy skills, and professional development that considers what teachers will need to support productive joint engagement with media in their classrooms.

Openness to media use and access to technology. As noted above, many preschool educators are resistant to integrating media into their instruction, fearing that such media will take away from, rather than enhance, learning from rich social interactions (Bayhan et al., 2002). A precondition for technology integration at any level of the educational system is an openness to technology and media use, as well as a belief that it has the potential to benefit learning (Ertmer, 1999). A curriculum supplement that augments—rather than replaces—the regular curriculum in literacy or any other domains may be seen as reducing the risk of harm and enabling exploration of new approaches to teaching.

Likewise, use of media requires access to digital technology for viewing video clips, playing games, and the like; it may also require internet access. Past studies have found that curriculum materials that employ technology can be difficult for teachers to implement as many preschools have limited access to technology and teacher training opportunities (Davidson, Fields, & Yang, 2009). Thus, a second critical condition is sufficient access to technology to implement media-rich materials as intended. Limiting the number of technology requirements can make it possible for a wider range of sites to participate and easier for teachers to learn how to integrate technology into their teaching.

Ensuring intensity of exposure to critical early literacy skills. Among the most critical early literacy skills for later reading are letter naming, identification of letter sounds, understanding concepts of story and print, and phonological awareness (Dickinson, McCabe, Anastasopoulos, Peisner-Feinberg, & Poe, 2003; Kendeou, van den Broek, White, & Lynch, 2009; Lepola, Poskiparta, Laakkonen, & Niemi, 2005; Nation, Marshall, & Snowling, 2001; Storch & Whitehurst, 2002; Whitehurst & Lonigan, 1998). At the same time, early literacy is multidimensional and individual skills not only predict different aspects of later reading success but also develop in relation to one another (Lonigan, Burgess, & Anthony, 2000; Sénéchal, LeFevre, Smith-Chant, & Colton, 2001). As a consequence, the National Early Literacy Panel recommends instructional programs focus on multiple skills and incorporate multiple research-based strategies for developing them (National Institute for Literacy, 2008).

Literacy interventions that incorporate digital media reflect the need to address different kinds of early literacy skills in sequence and in varied formats. Researchers hypothesize that interactions with digital media may work synergistically with traditional print activity, enabling teachers and other guides to vary formats and exploit more opportunities for repeated practice (Desmond, 2001; Kendeou et al., 2005; Linebarger, 2001; Neuman, 1995). One strategy for facilitating learning from interactions across media is to focus intensely on a few critical skills and employ media resources from multiple programs or properties with which children are familiar. Different programs focus on slightly different skill sets, and just as important, employ different strategies for teaching the same skills. Repeated viewing of clips, engagement with games, and participation in hands-on activities enables a focused supplement of limited duration to present multiple research-based strategies for developing students' ability to name letters, identify letter sounds, and be aware of phonemes.

Professional development for teachers. Though research studies show that adults' instructional mediation of children's media use can support children's learning, it is uncommon in naturalistic interactions (Austin, Knaus, & Meneguelli, 1997; Barkin et al., 2006), especially in low-income communities (Warren, 2005). Likewise, studies show that simply providing technology access to teachers and students in disadvantaged communities is unlikely to help increase equity of opportunity to learn from media, if there is not also mentoring available to help make productive use of media for learning (Neuman & Celano, 2006). Professional development that takes into account both the need for teachers to develop powerful strategies for guiding children's engagement with digital media and to troubleshoot technology as it arises is a critical condition for successful implementation of a media-rich curriculum supplement for preschools.

One strategy for professional development that allows for flexibly meeting diverse needs of teachers with respect to both pedagogy and technology is to rely strongly on instructional coaching. Increasingly, teachers enacting a new curricula have the opportunity to interact with an instructional coach or mentor, who can support them in introducing new instructional practices consistent with research on effective instruction (Girolametto, Weitzman, Lefebre, & Greenberg, 2007; Landry, Anthony, Swank, & Monseque-Bailey, 2009; Pianta, Mashburn, Downer, Hamre, & Justice, 2008; Ramey & Ramey, 2006; Wasik, Bond, & Hindman, 2006). Coaches have proven especially helpful in supporting teachers' integration of technology into instruction in the elementary and middle grades, providing them not only with necessary instructional support, but also technical support (Glazer, Hannafin, & Song, 2005).

5. The present study

The present study tested the efficacy of a curriculum supplement that integrated print-based activities with content from video clips and games associated with three public education television programs *Sesame Street*, *Between the Lions*, and *SuperWhy!* In studying this supplement, our purpose was to test whether a literacy curriculum supplement integrated with public media can improve literacy outcomes for young children, when compared to a science-focused supplement.

The efficacy study used an experimental design to estimate the impacts of the curriculum supplement on letter identification, the sounds letters make, the initial sounds of words, and concepts of story and print. A total of 80 preschool classrooms serving primarily low-income children were assigned to either a treatment or treated control condition. In the treatment condition, teachers received professional development and necessary materials to implement the media-rich literacy supplement. In the control condition, teachers received professional development and necessary materials to implement a media-rich supplement focused on science. Teachers in both conditions were instructed to continue to implement their regular literacy instruction during the study.

Our design for the control group reflected three sets of concerns. First, we were primarily interested in testing the impact of the digital *content* from PBS programs on children's learning and not the specific contributions of media or technology to learning. Although other researchers have focused on the impact of media and technology on children's early literacy learning (Pasnik et al., 2007), the policy evaluation question of interest to the U.S. Department of Education was whether educational television programming could be effective in improving literacy outcomes of low-income children when integrated into a curriculum supplement for preschools. Second, we incorporated technology and coaching into the control group, because we were aware that in many preschools, media use is controversial. All volunteers in the study would be asked to incorporate media into their instruction, regardless of the outcome of random assignment. Third, in the treated control group, incorporating technology allowed us to guard against possible Hawthorne and halo effects. Hawthorne effects can arise in observational and experimental studies when participants orient their behavior toward the perceived goals of researchers, on the basis of their understanding of the research situation (Adair, 1984; Landsberger, 1958). We were particularly concerned with possible Hawthorne effects of giving resources and providing extra attention to teachers in treatment classrooms as professional development offerings to this population tend to be few. We also were concerned that the addition of new technology might increase student engagement in ways that could make attributing results to the content of the intervention difficult because of halo effects. Halo effects linked to the novelty of instructional materials have long been acknowledged as a threat to validity of studies involving digital media (Clark & Sugrue, 1991). Thus, we decided to encourage teachers to provide students with an equivalent amount of access to digital media in the comparison group.

As in other efficacy studies (Flay et al., 2005), we estimated impacts of the curriculum under conditions we considered to be ideal, as outlined in the literature review. As part of the study, we made sure teachers had access to educational media in their classrooms. Furthermore, our choice to employ a treated control group that also required the use of media was intended to draw volunteers that were open to the use of media at the outset of the study, ensuring that both experimental conditions would be staffed by teachers comfortable with media use. As part of the study, we also provided all necessary materials to teachers and guidance to them regarding levels of exposure hypothesized to be sufficient to improve learning. Third, we provided instructional and technical support in the form of coaching to teachers implementing both the treatment and control curriculum supplements.

The study design attempts to address limitations identified above of previous studies. The number of classrooms incorporated in the current study ($n = 80$) is much larger than in previous studies of curriculum supplements that incorporated content from public television programs into preschool settings ($4 \leq n \leq 28$). In addition, the sample, as we describe below, includes a broad diversity of settings and children from a wide range of cultural and linguistic backgrounds. The large and diverse sample allowed us to estimate the robustness of effects across different types of settings.

6. Method

6.1. Sample

Recruitment for the study took place in the New York City and the San Francisco metropolitan areas, where researchers were located. Researchers used a combination of flyers sent through local networks of early childhood education and care providers, presentations at meetings, and one-on-one meetings inviting preschools to participate. Outreach materials described the incentives for participation: opportunities to receive staff training, supplemental materials, video segments and computer games for children to take home, $200 cash incentives for teachers, and a cash incentive of $500 for each class that successfully completed the requirements of the study.

To be eligible to participate in the study, teachers needed to meet a number of requirements. Their class had to have at least four children between the ages of three and a half and four and a half who had enough knowledge of English to be assessed in English. The classroom had to have access to a computer with a DVD player for showing video segments. Teachers also had to be willing to receive coaching, allow for periodic visits from researchers, and to implement the supplement for the full duration (10 weeks). Centers had flexibility in scheduling how they would implement the program, but they were asked to implement all program elements (video clip viewing, online game playing, participation in teacher-led activities) for two and a half hours each week.

A total of 80 teachers participated in the study, 47 in New York City area and 33 in the San Francisco area. With respect to mean level of education and pre-implementation classroom quality for literacy learning, classrooms in the study did not differ across the treatment and control conditions (Table 1).

Scores on the Early Language and Literacy Classroom Observation (ELLCO; Smith & Dickinson, 2002) are our best source of common data on literacy practices in classrooms, because centers used a wide variety of curriculum frameworks and materials. Those classrooms rated "high" were ones in which observers found compelling evidence that teachers initiated and fostered extended conversations across activity centers, called attention to the sounds

Table 1
Characteristics of teachers in the study.

	Overall sample	Treatment teachers	Control teachers
N of teachers	80	39	41
Highest level of education			
Percent with high school diploma or less	1.3	0.0	2.5
Percent with some college or technical school	13.8	15.0	12.5
Percent with associate's degree	7.5	12.5	2.5
Percent with bachelor's degree	28.8	27.5	30.0
Percent with graduate or professional's degree	20.0	17.5	22.5
Percent missing	28.8	27.5	30.0
Classroom ELLCO score			
Percent rated high	15.0	12.8	17.1
Percent rated medium	60.0	61.5	58.5
Percent rated low	25.0	25.6	24.4

of language, and helped children learn new words. These classrooms had a large variety and number of books, and used books across the classroom. Teacher book readings effectively modeled language and concepts of story and print for children. In this sample, none of the classrooms scored the maximum number of points from component scores that informed observers' ratings. In classrooms rated "medium," observers found some evidence that teachers initiated and fostered conversations with and among children, but less often and/or in fewer activity settings. Teachers sometimes called attention to the sounds that make up language or helped children learn new words. These classrooms had books, but the variety and/or number of books was more limited. Teachers used books in fewer activity areas, and teacher book readings did not necessarily model language and concepts of story and print. In classrooms rated "low," observers found limited evidence that teachers initiated or fostered extended conversations with children, called attention to the sounds that make up language, or helped children learn new words. Books in these classrooms were limited in number and variety, and, if present, were used books in a small number of classroom areas. Teacher book readings, if they occurred, did not effectively model language or concepts of story and print.

On average, classrooms had between 14 and 26 children eligible for the study. Within classrooms of teachers in the study, we selected five children at random to participate in the study. A screener was used to ensure that each child was in the age range of the study and could be tested in English. To determine language proficiency, assessors used a brief three-question screener. The screener did not exclude children whose primary language was not English, only children whose English language skills were so low that assessors believed a valid assessment of their skills could not be obtained. Only four children who had been selected at random for participation in the study were identified as ineligible for study participation.

There were no significant differences between treatment and control group children with respect to their mean age, poverty status, gender, ethnicity, whether they spoke English at home, mother's education, and number of books for children in the home (Table 2).

Table 2
Characteristics of children in the study.

	Overall sample	Treatment children	Control children
N at pretest	436	210	226
N at posttest	396	197	199
Mean age at start of implementation (*SD*)	56.7 (2.9)	56.7 (3.8)	56.6 (3.0)
Percent female	51	51	50
Income			
Percent low income[a]	68	74	63
Percent not low income	18	15	21
Percent missing	14	11	17
Ethnicity (% of non-missing)			
White	6	4	7
African American	28	33	23
Hispanic	53	47	59
Asian or Pacific Islander	10	12	9
Native American	3	4	2
Missing	4	2	5
Highest level of mother's education (% of non-missing)			
Less than high school diploma	26	30	23
High school diploma	33	34	33
Some college or technical school	20	19	20
Associate's degree	6	5	7
Bachelor's degree	9	6	12
Graduate or professional's degree	5	6	5
Missing	44	45	44
Mean log number of books in the home (*SD*)	3.2 (1.1)	3.1 (1.1)	3.4 (1.1)
Percent missing number of books	42	41	44
Mean pretest scores on outcome measures (*SD*)			
Letter name knowledge(upper case letters) (Max possible = 26)	14.71 (10.34)	15.75 (10.16)	13.74 (10.44)
Letter Sound Awareness (Max possible = 26)	5.82 (7.37)	5.49 (6.71)	6.13 (7.94)
Beginning Sound Awareness (Max possible = 11)	4.10 (3.53)	4.11 (3.53)	4.08 (3.53)
Story and Print Concepts (Max possible = 19)	9.40 (4.14)	9.83 (4.11)	9.40 (4.14)

[a] Low income is defined as individuals whose income is low enough to make them eligible for a government subsidy to support the cost of attending the early childhood education center.

Attrition during the study was low. No classrooms dropped out of the study from the time random assignment was conducted to the end of the study. Beginning with a sample of 436 children, a total of 37 children (8.5%) who completed pretests did not complete any posttests. Children who dropped out of the study were not different from those who remained in the study on any of the pretest literacy measures.

6.2. Treatment group materials

Below, we elaborate on the organization of the *PBS Kids Raising Readers Curriculum Supplement* that is the focus of this study, describing its key components and how they are integrated.

Curricular focus and duration. The curriculum supplement focused on developing four early literacy skills: letter naming, identification of letter sounds, understanding of story and print concepts, and phonological awareness. Letter naming activities targeted children's ability to learn, recognize, and name the symbols for upper case letters. With respect to letter sounds, the aim was to develop activities that helped children connect sounds to the corresponding symbols for upper case letters. Concepts of story and print activities targeted children's skills related to print and books. In particular, the curriculum supplement focused on helping children learn to identify the front cover, title, and author of a book, how to open a book and turn the pages, recognize that English print is read from left to right and from top to bottom of a page, and recall verbally simple elements of a story read to them by an adult. Finally, phonological awareness activities emphasized skills like rhyming, counting sounds in words, matching sounds, and blending sounds. In particular, the curriculum supplement engaged children in listening to letter sounds and rhymes, and matching sounds.

The curriculum supplement took 10 weeks to implement and was intended to provide participating children with 25 hours of activities. These hours were in addition to the literacy program already in place within the participating centers. The supplement called for children's repeated, guided viewing of video segments and whole episodes, playing of online games, and participation in other teacher-led activities that did not include digital media. Repetition did not take place on consecutive days; rather, repeated viewings of segments took place over multiple weeks, as part of a review of skills introduced in earlier weeks. A synopsis of the curriculum supplement, a recommended weekly schedule, and a mapping of several activities to evidence-based strategies for teaching early literacy skills all appear in Appendix (Parts A–C).

Specification of the teacher and child interaction during activities. The curriculum supplement integrated video segments and online games with other teacher-led, interactive literacy activities that did not include digital media. Sesame Workshop, WGBH Boston/Sirius Thinking, and Out of the Blue Enterprises produced the digital content (video segments, whole episodes, and games) for the intervention, using material from the public television programs *Sesame Street*, *Between the Lions*, and *SuperWhy! Sesame Street* and *Between the Lions* video segments focused on the target skills of letter naming and letter-sound identification. All three programs and their online games aim to support the development of early literacy skills of children ages three to five, the target ages for the study. Entire episodes of *SuperWhy!* were included because the program uses a narrative-format. Selecting segments would have made it difficult for children to engage with the storyline that connects and draws added attention to particular opportunities to learn. Children gained additional practice in letter naming, letter-sound identification, and guided spelling during viewings of *SuperWhy!* The content for all three programs is available through the web and as part of broadcast programming offered by local PBS stations. Researchers added teacher-led activities that focused on the letters and skills of the clips viewed for the week; these activities included practice with reading, writing, and making the sounds of letters, listening to stories, and naming conventions of print as stories were read to children.

The curriculum supplement employed multiple instructional strategies for developing focal skills. For example, the intervention called for teachers to introduce key vocabulary, letters, and sounds before introducing video segments, interact with children during segments and episodes to focus their attention on text, and reflect upon content embedded in the segments. Active viewing and post-viewing reflection activities repeated the actions of characters, such as writing letters in the air as the fictional character "Princess Presto" does in *SuperWhy!* episodes. Teachers participating in the literacy program received teachers' guides containing daily scripts and 10 weeks of activities, as well as manipulatives, such as magnetic letters, clay, pointers, alphabet charts, and letter and word cards, to establish a print-rich literacy environment for children and enable more embedded literacy instruction. The intervention called on teachers to model concepts of print and emphasize oral language during twice weekly book readings. To support these readings, each class received five picture books.

In order to increase the quality of the supplement, researchers provided instructional coaching in order to support preschool teachers. Professional development included a brief, two-hour orientation led by an assigned coach to familiarize them with the materials and key elements of the curriculum. After training, coaches provided teachers with on-site support that included modeling instruction, assisting teachers with implementation, and observing and providing constructive feedback. Coaches were instructed to visit classrooms weekly for the first five weeks of the supplement and every other week in subsequent weeks. During their visits, coaches negotiated their role in leading instruction: they could lead activities with the teacher observing, co-lead activities with teachers, or observe as teachers led activities. When observing, teachers were given guidelines about how to provide feedback to teachers to improve fidelity of implementation. Study leaders advised coaches to fade their support when visiting classrooms over time, initially leading lessons but later just observing them. In practice, overall the pattern of coach activities across weeks of the intervention showed good adherence to this guideline (see Martin et al., in press, for more details on the enactment of the coaching model and teachers' perceptions of its value).

After the first five weeks, coaches could decide how often to visit classrooms, in consultation with the study team directors. If a site was having difficulty with implementation, then the coach was to visit the site. Training for coaches provided them with criteria for deciding whether a site was experiencing difficulties. If a site was having difficulty with technology access or with implementing any of the core program components—video viewing, game play, or hands-on activities—that site was flagged for study directors in a weekly report by coaches completed online. Study directors then discussed with coaches how to allocate time and support to the site for the coming week or weeks. Though this might have produced wide variation in classrooms' access to coaches, data from logs described below show limited variability in the amount of coaching received.

Integration of supplement components. The research team undertook several steps to ensure that these different components (digital media, materials, and coaching) fit together in ways that maximized benefits for children. First, the team followed an *Understanding by Design* approach (Wiggins & McTighe, 1998) to developing activities, beginning with the target skills, considering the likely assessments to be used, and then identifying activities that employ both explicit and embedded instructional strategies that would best support the development of target skills. The Appendix lists the various activities incorporated into the supplement by target skill.

Second, the team developed common qualifications for coaches and coaching guides that specified their roles and responsibilities. As part of their roles and responsibilities, coaches were expected to model activities initially but then to gradually reduce the support for implementation they provided to teachers. Third, the research team had a coordinated coach support plan that included just-in-time troubleshooting and feedback provided by coaches to the research team, so that implementation issues could be addressed in ways that enabled activities to be enacted as intended.

6.3. Treated control group materials

The comparison group supplement focused on science, not literacy, and it also included media elements. The supplement was of the same duration as the literacy supplement (10 weeks), and like the literacy supplement, it integrated video from educational television programs and associated online games with classroom activities. The curriculum supplement combined full episodes of *Sid the Science Kid* (produced by KCET/Los Angeles with Jim Henson Productions) and self-contained "focused viewing" segments from *Peep and the Big Wide World* (produced by WGBH Educational Foundation). Teachers guided children in exploring *science content* that was conceptually linked to transformation and change. Activities and instructional content were based on everyday experiences that were easily observable with the five senses. Teachers assigned to the control group also received coaching; teachers provided parallel training and guidance to coaches about how to support implementation. Results of the analysis of science outcomes for the treatment and comparison groups are not presented here; those results, but not the results presented in this paper, can be found in Penuel et al. (2010).

Of concern to us in this design was the possibility that this choice to focus on science would lead to students being exposed to significantly more literacy instruction in the treatment condition, and, likewise, that children in the comparison condition might receive less time for literacy instruction. We therefore analyzed minutes of instruction in literacy offered on a weekly basis in both conditions. An analysis of teacher-reported number of minutes of literacy instruction per week revealed no differences between the treatment and control groups at the start of the supplement; assignment to condition did not result in a significant change in the total amount of literacy instruction offered to children, either.

6.4. Measures

Implementation: Teacher instructional mediation of co-viewing during coach visits. Coaches reported on teacher roles using an implementation log to describe what the teacher's role was during the activities from the day by selecting one of the following responses: teacher was engaged in another activity in the room; teacher observed the activity; teacher participated in the activity alongside the children; or teacher led or directed the activity. For each day, coaches could mark all roles that applied across the different activities of the session.

Implementation: Teacher instructional mediation of co-viewing between coach visits. Each week, on their own and without coaches present, teachers were to mediate engaged co-viewing of four different video segments. Coaches collected data each week, in person or via telephone (depending upon whether the coach was present), using the implementation log, as to whether teachers showed each video to children with or without active mediation by the teacher or not at all. For one of the four videos shown each week, teachers were to interrupt the video to engage in practice of the skill depicted in the video. This particular type of activity required the most of teachers in mediating co-viewing, because it required them to orchestrate a sequence of activities that alternated between guided video viewing, teacher–child interaction, and independent practice by children.

Dependent variables (child level). Early literacy skills (letter name knowledge, letter sounds, and beginning sound awareness), and concepts of story and print were included as outcome measures in the study.

Early literacy skills. Three subtests of the Phonological Awareness Literacy Screening for pre-Kindergarten (*PALS-PreK*) were used to measure three early literacy skills: Letter name knowledge, Letter Sounds, and Beginning Sound Awareness. The letter name knowledge subtest of the PALS-PreK measures knowledge of the 26 upper case letters when presented in random order. The letter sounds subtest requires the child to provide an appropriate sound (phoneme) that corresponds to each letter. Finally, in the beginning sound awareness subtest children must match 10 pictures based on their initial sound (phoneme).

Internal consistency estimates from pilot studies of the PALS-PreK (Invernizzi, Sullivan, Meier, & Swank, 2004) indicate adequate reliability for all three subtests. Interrater reliability for the Letter name knowledge subtest was 99%. Cronbach's alphas for the Letter Sounds and Beginning Sound Awareness subtests were high, at 0.93. Concurrent validity evidence reported in the technical manual comparing PALS-PreK scores a test of basic reading skills, the Test of Early Reading Ability (TERA-3); the correlation between the revised version of the PALS-PreK and the TERA-3 was medium-high and statistically significant ($r = .67$, $p < .01$; $n = 73$).

Story and print concepts. This measure, adapted from the TERA-3 Conventions Subtest by researchers at the University of Pennsylvania and Mississippi State University, assessed constructs targeted by the curriculum supplement related to book and story skills. The assessment included 14 items for which a total of 19 points were possible. Children scored points for being able to identify correct orientation of the book, left-to-right reading, title and author name, and key story elements when asked to recall them. No validity or reliability data are available for this measure.

Independent variables. The following variables were included in models as predictors or covariates. We collected additional background data on children, their parents, and their teacher, including children's age, ethnicity, and home language.

Treatment assignment (teacher level). We coded teachers assigned to the treatment condition as 1; teachers assigned to the control condition as 0.

Teacher's level of education (teacher level). Using data from a teacher questionnaire, we coded teachers' highest level of education as a 3-level ordinal scale (0 = Associate's degree or less, 1 = Bachelor's degree, 2 = Graduate or professional degree). Teacher education data were missing for 30% of the children.

Pretest score (child level). For each outcome measure, that outcome's pretest score was used as a covariate in all models.

Age at start of study (child level). Age in months was captured through an initial screening and consent instrument. Age was calculated for each child based on data captured in coaching logs about the start of the supplement. Age data were missing for 9% of the children.

Ethnicity (child level). Children's ethnicity was coded as a series of dummy variables. For each child, an indicator of whether the child was White, African American, Asian, or Pacific Islander or not was coded as 1 or 0. The largest category of children, Hispanic, was the omitted variable in models that examined the relationship between ethnicity and outcomes.

Mother's education (child level). Using a telephone-administered questionnaire, we gathered data on the child's mother (or female caregiver's) highest level of educational attainment. The highest grade achieved (ranging from 1 to 12) was treated as an interval scale. Mother's education data was missing for 44% of children.

Number of books in the child's home (child level). Using telephone questionnaire data, we created a variable for the number of books in the child's home. Since the data were not normally distributed, we transformed the data: the log of the number of books parents reported being available to children was used in models. This variable was missing for 42% of children.

Days between end of implementation and posttesting (control variable; child level). Effects can fade with time; the farther testing takes place from supplement implementation, the more children may forget what they have learned. Since there was some variation in the length of time between the end of the implementation and posttesting, we entered this length of time, using a combination of data from assessment forms and coach logs, as a continuous variable into our models. Data were missing for 12% of children.

6.5. Procedure

Random assignment of classrooms to condition. To increase the sensitivity of the experiment to impacts of the supplement and reduce the need for a much larger sample size, we introduced a blocking factor into the random assignment procedure. After recruiting teachers to participate in the study, we assessed their classrooms' literacy and language practices using the Early Language and Literacy Classroom Observation (ELLCO; Smith & Dickinson, 2002). The ELLCO includes a literacy environment checklist focused on the availability, content, and diversity of reading, writing, and listening materials; a classroom observation and teacher interview for rating teacher interactions with children and the environmental classroom supports for literacy; and a literacy activities rating scale derived from an observation of the frequency and duration of book reading and writing literacy activities. Summary scores (high, medium, and low) constructed for this study from the scales were combined with location (San Francisco and New York) were used to create six blocks. Within blocks, we used a random number generator to assign each teacher a number; we then rank-ordered the teachers on the basis of the random number for that teacher and assigned every other teacher to the treatment condition in the ordered list.

Determining child sample. After assigning teachers to conditions, the study team screened children, obtained informed consent from parents, and pretested children from teachers' classroom. The screening procedure focused on verifying study eligibility for each child in that teacher's classroom with the teacher. Children who would not be four years old by December 2008, who had any speech, hearing, vision, or learning difficulties or disabilities, or who could not follow directions in English were excluded from the study. The study team collected consent forms home from parents and randomly selected five children from each class who met eligibility requirements and who returned a consent form. Teachers and study team members assisted with follow-up.

Pretesting children. Upon receiving consents, a trained assessor scheduled a visit to each classroom to pretest all children using the early literacy outcome measures described above. Assessors were blind to the condition to which researchers had assigned each classroom. Assessors had past experience working with young children; the study team trained assessors both to follow ethical guidelines for the assessment set by the National Association for the Education of Young Children and in the proper administration of the specific measures used in the study. Training included simulated practice with use of the assessment battery.

Coach training. Prior to the start of the study, all coaches participated in a full-day training with the research team to review a study-specific coaching manual, list of materials provided to each classroom, scheduling recommendations, weekly tasks for coaches, and other information relevant to implementation. In addition, research team leaders familiarized coaches with the activities, media, and materials that comprised the supplement and prepared them to provide troubleshooting for technology issues. Throughout the training, the flexible nature of the coach's role was emphasized. The training also included a review of a weekly log form that coaches completed. Logs provided information on teachers' implementation of the supplement. The team supported coaches' work by providing weekly opportunities to review progress and challenges with a coach coordinator, one in New York and one in California. The coaching process was identical for the teachers assigned to the comparison condition, but the content was focused on science in this condition.

Coach support for implementation. Coaches provided assistance to teachers aimed at supporting their implementation of the supplement. As a first step in developing the coach–teacher relationship, coaches established contact with classroom teachers to set up an orientation session. During the orientation session, coaches reviewed the supplement goals, activities, and strategies, as well as expectations for implementation. Coaches reviewed materials that had been shipped to teachers and that included all the digital and print content required to implement the supplement. In the field, in the first four to five weeks of the supplement, coaches were instructed to lead activities that had been scheduled that day, co-lead them with teachers, or observe as teachers implemented the activities, as appropriate. In subsequent weeks, the study team gave coaches discretion as to how many times to visit sites, though they continued to make weekly contact with sites to complete implementation logs.

For the duration of the study, all classrooms implemented their regular literacy instruction. The extant curriculum in place varied widely from site to site. Detailed ELLCO subscale scores recorded by observers prior to beginning the study, however, provide a basis for comparing classrooms. Classrooms in both conditions were similar with respect to three major dimensions: the language environment, books and book reading, and engagement with print and early writing. On only one indicator—efforts to build vocabulary—were there any significant differences between the two classrooms with respect to the literacy environment. On that indicator, treatment classrooms provided lower support for vocabulary development than did comparison classrooms ($t = 1.95$, $p = .055$). Overall, classrooms presented fewer opportunities for students on this indicator, and they provided lower quality books for reading and limited opportunities for writing. However, classrooms rated higher on discourse climate, opportunities for extended conversations, organization of the book area, characteristics of books, and environmental print.

Though teachers did not report a significant change in the amount of literacy instruction offered to children, it is likely that some teachers did in fact replace their regular instruction during the time of the study, given this finding. Even so, the literacy supplement represented a modest, but focused intervention that targeted foundational literacy skills.

Posttesting. Within four weeks of completing the 10-week supplement, assessors returned to classrooms and completed posttesting of children who participated in the study. Upon successful completion of posttesting, teachers received their cash incentive for participation and additional materials related to both conditions in the study (early literacy and comparison) for use with children. The number of days between the conclusion of the intervention and testing ranged from zero to 29 days; the mean number of days was 6.9, and the median was six days.

6.6. Analytical techniques

In our study, children were nested within classrooms, and classrooms were the unit of treatment assignment for the study. Because of the nested, multilevel nature of the data, we employed hier-

archical linear modeling (Raudenbush & Bryk, 2002) to estimate treatment effects. In an initial set of models, we included a treatment indicator (Level 2, Teacher Level), pretest covariates (Level 1, Child Level), and dummy variables for each stratum (Level 2, Teacher Level) as predictors for each outcome. ELLCO scores were divided into tertiles, and in combination with the two states were used to form six strata, within which teachers were randomly assigned to one of two experimental conditions. Indicators for five of these strata were included in all models to improve statistical precision, as well as to ensure that the level-2 error terms were correctly specified as independent, identically distributed normal random variables.

For some of the measures, we detected significant level-1 heteroscedasticity in the error terms (in part due to ceiling effects of the test). For example, more than 20% of children scored perfectly on the Letter name knowledge and Beginning Sound Awareness scales. We corrected for this by splitting the pretests into five quintiles and modeling separate level-1 error variances for each quintile. We modeled a separate treatment effect for each pretest quintile using treatment-by-quintile interaction terms, and computed a single overall treatment effect by estimating the marginal effects over all quintiles. All predictors were treated as fixed effects.

For each outcome, three models were run. The first model estimated treatment impact and contained necessary indicators for sampling strata, treatment, pretest quintiles, and treatment–quintile interaction terms. The second model was similar to the impact model, and also included interaction terms for the treatment with a selected list of potential moderators (mother's education and child's eligibility for subsidized meals). The third model began with the impact model, and included a vector of teacher and student-level covariates for correlational analyses. These covariates included student age, time lag between end of lesson and post-test, student ethnicity, mother's education, number of books in the home (log scaled), and teacher's level of education. These models share a similar structure; the compact form is:

$$Y_{ij} = \sum_{p} \beta^{(p)} W_{ij}^{(p)} + (I_{ij}^{(1)} r_{ij}^{(1)} + I_{ij}^{(2)} r_{ij}^{(2)} + I_{ij}^{(3)} r_{ij}^{(3)} + I_{ij}^{(4)} r_{ij}^{(4)} + I_{ij}^{(5)} r_{ij}^{(5)}) + u_j$$

where Y_{ij} is the outcome (posttest) measure for student i in classroom j, W_p are the P student and classroom level predictors appropriate to each model, $\beta^{(p)}$ are coefficients corresponding to predictors $W^{(p)}$, $I_{ij}^{(q)}$ is an indicator for the pretest of student i in classroom j occurring within the qth quintile (1st quintile is the omitted category), $r_{ij}^{(q)}$ is the within-classroom error term for students in the qth quintile of the pretest, distributed as Normal (0, $V^{(q)}$), and u_j is the between-classroom error term, distributed as Normal(0, τ).

These models were fit with the `xtmixed` routine in Stata version 11. Because a significant proportion of family background and teacher data were missing for the correlational model, we computed values for the missing data via a multiple imputation algorithm (Rubin, 1987). We first determined that the probability of a variable value being missing did not depend on values of the pretest scores. Next, five imputation datasets were created, and the coefficients resulting from fitting models over these datasets were combined and standard errors adjusted to account for the uncertainty introduced by imputation. The ice routine in Stata/11 (Royston, 2004) was used to perform the computations.

7. Results

7.1. Implementation of key components of the supplement

During sessions when coaches were present, treatment teachers led activities themselves in 72% of the sessions and co-participated in activities in 38% of the time, indicating that in most of those activities, teachers mediated engaged co-viewing with children. In just 20% of the sessions when coaches were present were teachers observed to be engaged in an activity unrelated to the intended supplemental activity. We generated a score for each teacher, indicating the percentage of classes in which the teacher met or exceeded the recommended time spent in six critical activities (see Table 3). Treatment teachers were on average able to implement the full warm-up and episode viewing activities in nearly all classes (99% and 98%, respectively). Teachers were also able to view videos for the recommended time in most classes (89% of classes), conduct the hands-on follow up activity (78%), have students play the computer game (86%) and conduct a review (94%).

Table 3
Descriptive statistics for implementation.

	Treatment	Control
Distribution of coach visits		
Percent planned, but not completed	24	28
Percent completed	58	55
Percent not planned	18	16
Mean duration of coach visit in minutes (*SD*)	140.8 (46.8)	153.7 (84.1)
Coaches observed teachers... (percentage of visits)		
Engaging in another activity in the room	20	8
Observing the activity	12	11
Participating in the activity alongside the children	38	36
Leading or directing part of the activity	72	69
Not present for any of the activities	2	5
Percent of classes reporting recommended time spent...		
Doing a warm-up (5 min)	99	94
Viewing whole episodes of Sid (35 min)	98	90
Viewing videos of Sid, Kids Explore or Peep (75 min)	89	84
Doing a hands-on follow up activity (60 min)	78	82
Playing computer game (10 min)	86	75
Doing a review (5 min)	94	92

7.2. Impact analysis

We began the model building process by fitting an impact model for each outcome with the treatment indicator and indicators for quintiles of the corresponding pretest score (see Table 4) We computed a marginal treatment effect by computing a weighted mean effect for each of the five pretest quintiles, using the `margins` routine in Stata version 11 to compute standard errors and p-values for the marginal effects. Controlling for pretest scores, the treatment condition predicted statistically significantly higher marginal posttest scores for two measures: upper letter naming and letter sound awareness ($p < .001$). The treatment effect for concepts of print was marginally significant ($p = .06$). The one nonsignificant difference was for initial sound awareness. The greatest gains were generally found for those students starting in the lowest quintile of the pretest scores.

7.3. Effect sizes

Effect sizes were computed by dividing the estimated marginal treatment effect by the pooled standard deviation of the posttest scores. The total standard deviation (as opposed to the within-site or between-site standard deviation, see Hedges, 2007) was used in the denominator of the computation. This effect size is analogous to the effect sizes reported for studies without statistical clustering. The largest average effects of the early literacy supplement

Table 4
Model results: pretest covariate only.

Predictor	Letter name knowledge		Letter Sound Awareness		Beginning Sound Awareness		Story and Print Concepts	
	β	*SE*	*β*	*SE*	*β*	*SE*	*β*	*SE*
<Intercept>	4.99***	1.242	2.86	1.470	4.37***	0.817	5.88***	0.920
Treatment indicator	7.58***	1.765	3.21**	1.037	0.26	0.634	1.35	0.745
Pretest (2nd quintile)†	5.89***	1.502	1.80	1.294	−0.87	0.960	1.63*	0.666
Pretest (3rd quintile)	15.99***	1.314	1.01	1.001	1.75*	0.691	3.76***	0.660
Pretest (4th quintile)	19.67***	1.186	6.44***	1.035	3.39***	0.649	4.94***	0.741
Pretest (5th quintile)	[a]		11.17***	1.029	4.91***	0.584	6.64***	0.685
Treatment × Pretest (2nd quintile)	−0.99	2.259	0.25	1.701	1.39	1.251	0.59	0.954
Treatment × Pretest (3rd quintile)	−5.42**	1.958	2.51	1.498	0.74	0.994	−0.58	0.925
Treatment × Pretest (4th quintile)	−7.06***	1.783	0.59	1.400	0.82	0.930	−0.41	1.089
Treatment × Pretest (5th quintile)	(note 1)		1.08	1.538	0.52	0.861	−0.93	0.935

[a] Because nearly a quarter of the pre-test responses for letter name knowledge were perfect scores, it made more sense to split this measure into four quartiles rather than five quintiles.
† $p < .10$.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

were for letter sound awareness, where children gained one half a standard deviation more than in control classrooms (*ES* = +0.55). Children in the early literacy supplement classes outgained children in the control condition by nearly one third of a standard deviation on the measure of letter name knowledge (*ES* = +0.42) and by one quarter of a standard deviation on the measure of story and print concepts (*ES* = +0.24). The effect size for beginning sound awareness was +0.20, but the effect was not statistically significant.

An alternative to calculating effect sizes is to examine the proportion of posttest variance explained by the treatment. In a 2-level model with treatment assignment at the teacher level, we expect to primarily observe a reduction in the level-2 variance. The proportion of variance explained between teachers ranged from 11% (Beginning Sound Awareness) to 35% (Letter Sound Awareness), with an anomalously small between-teacher variance component estimated for Letter name knowledge (0%). The proportion of total variance explained corresponds to the R^2 statistic in ordinary least squares regression models.

7.4. Moderator analysis

After establishing the main effect of the treatment, we tested two variables as potential moderators of the treatment effect: mother's education and child's eligibility for subsided meals. Using the multiply imputed data, models were fit on each student outcome using the pretest score, treatment, the moderator, and the treatment-by-moderator interaction term as predictors. The hypothesis that all treatment-by-moderator interactions within a model were jointly equal to zero was tested with a Wald test. In no cases were either of these potential moderators statistically significant. These results suggest that impacts were robust to variations in parent education and poverty status.

8. Discussion

The study found that a media-rich curriculum supplement that employs content from PBS educational programs can have a positive impact on early literacy skills of preschoolers from low-income backgrounds. Findings corroborate those from an earlier outcome study (Prince et al., 2002) that found positive impacts of integrating digital media content from PBS programs into preschool classrooms on early literacy skills. That positive results from this study were obtained in the field, in the context of a large randomized controlled trial, distinguishes them from Prince et al. study. The earlier study included just four centers in its analyses. Further, in contrast to the earlier study, findings were more consistently positive across all outcomes measured in the study. Study results are also consistent with positive findings from smaller-scale studies conducted in the field as part of the *Ready to Learn Initiative* (Linebarger, 2009; Neuman et al., 2010).

One benchmark for judging the significance of the magnitude of effects is to compare them to results of studies of other full-year curricula widely used in preschool settings serving primarily low-income children. Effects from the current study were all larger than most reported in a recent review of effectiveness studies for 14 preschool literacy curricula (Preschool Curriculum Evaluation Research Consortium, 2008). That study found effects of curricula on the Prekindergarten Comprehensive Test of Phonological Processing, which includes measures of letter naming and letter sounds, of between −0.07 and +0.32. Only two curricula reviewed in the report had higher effects than the lowest significant effect in our study. Further, a limitation of many code-focused interventions is that some that have been judged effective are not commercially available and are not designed to be used with a whole class (Shanahan & Lonigan, 2010). By contrast, nearly all of activities and the synopsis of the current curriculum supplement are freely available and can be used as part of whole-class instruction.

Another important finding was that teachers reported that they were able to guide the media engagement for their children as intended in the supplement. This finding is significant, as past studies have found teachers have difficulties implementing interventions that incorporate technology (Davidson et al., 2009). In the current study, not only did teachers report that they were able to use digital media as often as intended, they were able to follow the specific sequence of the curriculum supplement and guide children's engagement with media across multiple platforms (computers and videos). The result was that teachers reported that children had the intended level of exposure to opportunities to develop targeted early literacy skills in a wide variety of formats and in the sequence that reflected the likely ways children's different skills would co-develop.

Intervention research in which the best strategies from research are combined into a single program, curriculum, or supplement necessarily make it difficult to make causal claims about what strategies contributed to any observed effects. In this study, we did conduct correlational analyses to explore relationships between implementation components and outcomes. In these analyses, we fit multilevel mediation models (Krull & MacKinnon, 1999) that explored whether the amount of time spent viewing videos, playing games, and engaging in hands-on literacy activity (separately) mediated children's gains, but none of these were significant predictors. Studies powered to detect a particular minimum impact

effect are typically underpowered to detect significant correlations, and that was the case here: implementation levels of different components did not explain a significant percentage of variance across classrooms in treatment effects.

8.1. Study limitations

One consequence of our decision to hold media and attention to teachers through professional development constant (to minimize potential halo and Hawthorne effects) is that we did not provide students with an alternative supplement in the domain of literacy. This kind of comparison group would have provided an especially strong basis for testing the efficacy of media-rich curriculum materials (National Research Council, 2004). At the time of the study, however, no suitable curriculum supplement of a similar duration and with a similar mix of activities and teacher support was available for use. Because implementing the supplement might have increased children's total exposure to literacy activities each week, we did analyze whether implementation of the supplement enhanced children's total exposure to literacy activities relative to the comparison group but found no differences. One possible explanation for this fact is that teachers did replace their regular instruction in literacy with the supplement during this study, despite instructions to them to continue implementing their regular literacy instruction. A future research study to replicate these findings should, however, compare the effects of curriculum supplements of a similar duration and/or with similar levels of support, especially to understand the unique contribution of media elements to the supplement. Such a study should also take care to document how implementation of such a supplement alters the nature of literacy instruction in those classrooms and to rule out with greater confidence the possibility that the effect is due simply to more time on task.

Similarly, future studies might seek to distinguish the specific elements of the curriculum package that were most important for children's learning by separating them back out and studying individual components in experimental studies, as we were not able to develop hypotheses about the relative contribution of elements from mediation analyses. If, however, for budgetary reasons, teachers or districts were interested in using only parts of the supplement, future studies should determine what elements are integral to the curriculum's success and what elements might be excluded without compromising the potential efficacy of the supplement. For example, given that an intensive coaching model was an integral part of this curriculum, future studies could examine what level of coaching is needed to sustain impacts on children's literacy, particularly whether less professional development would still be effective in increasing children's literacy. Such studies would be valuable as resources for professional development are scarce, such that identifying the threshold at which it becomes effective can help guide policymaking. Past research has examined the efficacy of coaching of preschool teachers to support implementation of curriculum at scale, but findings from these studies have drawn different conclusions about the value of coaching (Assell, Landry, Swank, & Gunnewig, 2006; Landry et al., 2009; Lonigan, Farver, Phillips, & Clancy-Menchetti, 2011; Ramey & Ramey, 2006), and none have focused specifically on identifying thresholds that matter for efficacy.

Another limitation of the study was that two of the study measures had limited data on reliability and validity. The Story and Print Concepts measure, while adapted from a standardized measure, was not tested for reliability or validity in the field, due to limited resources for conducting such a test. In addition, resources were not available to study implementation using more objective measures than the implementation logs kept by coaches. When coaches were on site, evidence of implementation came from direct observation of coaches; however, when coaches were not present, they relied on teacher reports. Coaches' relationships to teachers may have biased upward teachers' reports of active co-viewing between visits. Employing a consistent method of data collection and relying on researchers to gather data on reliability would have improved the quality and trustworthiness of implementation data.

A fourth possible limitation pertains to the generalizability of findings to other metropolitan areas and to rural areas. These two metropolitan areas represent both distinctive service areas for preschool and, our recruiting efforts suggested to us, different areas with respect to attitudes toward media in preschool education (one of the two regions proved easier to recruit participants to the study). In addition, compared to rural areas, children may have different levels of exposure to public media at home. Future replication studies would need to explore impacts on low-income children living in other urban areas and in rural areas. Such research might also employ an ecological perspective on children's learning from joint engagement with media (see Barron, 2010), which takes into account the multiple settings in which children encounter messages and skills that might help them learn.

9. Conclusion

The results of this study support the idea that the inclusion of digital literacy content from public media producers in preschool curriculum supplements holds potential for improving literacy outcomes. Low-income preschool-aged children with the lowest early literacy skills could show the greatest literacy gains most from such policies, if these results are generalizable to sites similar to the ones in the study; a future study could test this hypothesis by focusing on children whose profile is most similar to those in the lowest quintile of this study. Curriculum supplements such as this one also have the potential for broad impact, because they are usable in a wide range of preschool contexts and rely on digital content that is freely available on broadcast television or over the Internet. To be sure, children from disadvantaged families are less likely to attend early education programs (Magnuson, Meyers, Ruhm, & Waldfogel, 2004). Additional research is needed to determine if digital content can support the development of early literacy skills that are more difficult to teach and that are less malleable than code-related skills, such as comprehension (Dickinson, Golinkoff, & Hirsh-Pasek, 2010; Pearson & Hiebert, 2010), and whether it can support learning in other content areas. Some research exists to support the idea that such content can develop comprehension skills in the context of television viewing (Uchikoshi, 2005), but not yet when integrated into a coherent curriculum supplement. Regardless of the outcomes of this additional research, however, this study provides important preliminary evidence that public media programming designed for homes can be used in the classroom to help close literacy gaps between low-income and more economically advantaged children.

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Ready to Learn Summative Evaluation
EDC/SRI Study Design, Shelley Pasnik, PI

Prekindergarten Randomized Controlled Trial Study

In project year 2012 – 2013, the EDC/SRI team, Summative Evaluation researchers for the CPB-PBS Ready to Learn (RTL) Initiative will design and implement a large-scale randomized-controlled-trial (RCT) to measure the efficacy of a media-rich early math curriculum supplement that includes public media resources developed by RTL producers. The study will focus on child learning outcomes—whether participating in the Math Curriculum Supplement enhances children's mathematics knowledge and skills—and teacher outcomes—possible shifts in the attitudes, beliefs, and instructional practices related to math learning and the use of media/technology of teachers who enact the curricular supplement.

The study will take place in approximately 92 preschool classrooms in New York City and the San Francisco Bay area. Classrooms will be randomly assigned to one of three study conditions: treatment (consisting of the media-rich math curriculum supplement that incorporates Interactive Whiteboards (IWBs) laptop computers along with professional development for technology and supplement integration), treated control (consisting of IWBs and laptop computers along with suggestions of PBS resources, and professional development for technology integration) or a business as usual control condition (during which educators will engage in their typical math and technology use). At least 700 children will participate in all aspects of the study, including developmentally appropriate pre/post assessment of their mathematics skills and knowledge.

Research questions

The research questions guiding the study fall into three categories: child learning outcomes, teacher outcomes, and implementation.

1. ***Child learning outcomes***
    - To what extent do children in the treatment (intervention) condition perform better than children in the treated comparison (technology) and control (business-as-usual) conditions on measures of early math learning?
    - To what extent do children in the treatment (intervention) condition perform better than children in the treated comparison (technology) and control (business-as-usual) conditions on measures of self-regulation? [1]
2. ***Teacher outcomes***
    - To what extent do teachers in the treatment (intervention) condition report more positive attitudes and beliefs and improved practices, relative to teachers in the treated comparison (technology) and control (business-as-usual) condition?
3. ***Implementation***
    - To what extent do teachers in the treatment group implement the intervention with fidelity?
    - What is the relationship between fidelity of implementation and child learning outcomes?
    - What are the successes and barriers, if any, that teachers in the treatment group encounter while implementing the media-rich math curriculum supplement?

[1] The **main** impact question for the study focuses on math learning (namely, the target skills), but we are also examining potential impacts on self-regulation (skills that may be indirectly promoted through our activities) as an exploratory question.

Intervention

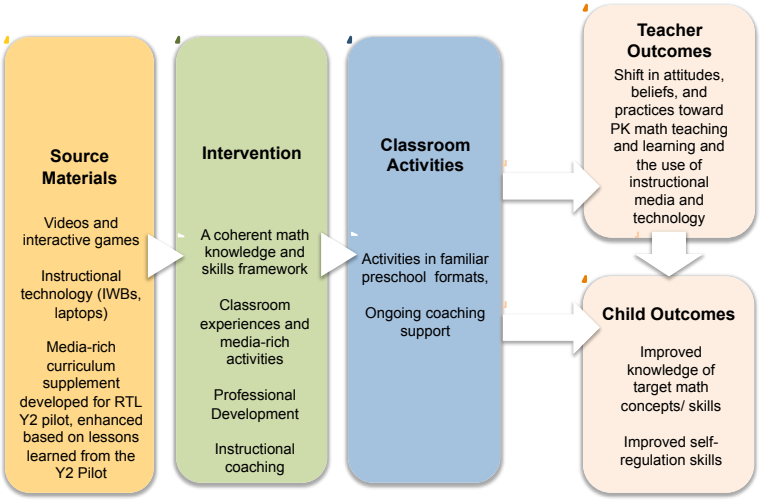
The RTL transmedia-rich math supplement is a ten-week mathematics curriculum supplement that helps support teachers' implementation of activities designed to capture children's interest and attention and promote children's learning of the following target math skills: counting; subitizing; recognizing numerals; recognizing, composing, and representing shapes; and patterning. Media properties (videos and interactive games) and technology resources (IWBs and laptops) comprise important material resources for the intervention.

The key features of the intervention include:

(a) **A structured curriculum supplement framework** that emphasizes target math knowledge and skills, and introduces and elaborates on these skills in a designed sequence;
(b) **A teachers' implementation guide** containing ten weeks of math learning activities**,** guidance for enactment, and instructional strategies for scaffolding children's math learning;
(c) **Teacher professional development sessions prior to implementation** that are designed to prepare teacher participants for implementation of the math curriculum supplement; and
(d) **Instructional coaching during the implementation period**, focused on providing 1-1 support to teachers during implementation that is tailored to their specific needs. Coaching will pay special attention to teachers' needs related to technology-supported mathematics instruction and will emphasize instructional strategies for integrating media (videos and games) and technology (IWBs and laptops) into instruction.

Theory of Change

Below is the hypothesized theory of change that underlies our research design. Moving from left to right, this diagram illustrates the various source materials, including the transmedia resources (videos and interactive games) and instructional technology that provide important points of departure for the development of the media-rich Math Curriculum Supplement.



The Next Generation Preschool Math project (NGPM) is a 4-year, $3 million research and development study, funded by that National Science Foundation, focused on the creation and integration of digital math content in the preschool classroom. Through an innovative partnership between learning scientists and early math learning experts from the Center for Children and Technology at EDC and SRI International, WGBH seeks to answer the question: *Can engagement with activities in a media-rich curriculum supplement improve low-income children's early learning of number and equipartitioning?*

Grant deliverables include:

1. Eight math iPad apps designed for preschool classroom use
2. Non-digital activities designed specifically to complement the iPad apps
3. A Teacher's Guide with monitoring of children's learning progress in the math apps

The curriculum covers two critical but under-studied preschool math concepts: "subitizing," the ability to say the number of objects in a group quickly and without counting, and "equipartitioning," or fair sharing of a group of objects or dividing a whole object into equal parts.

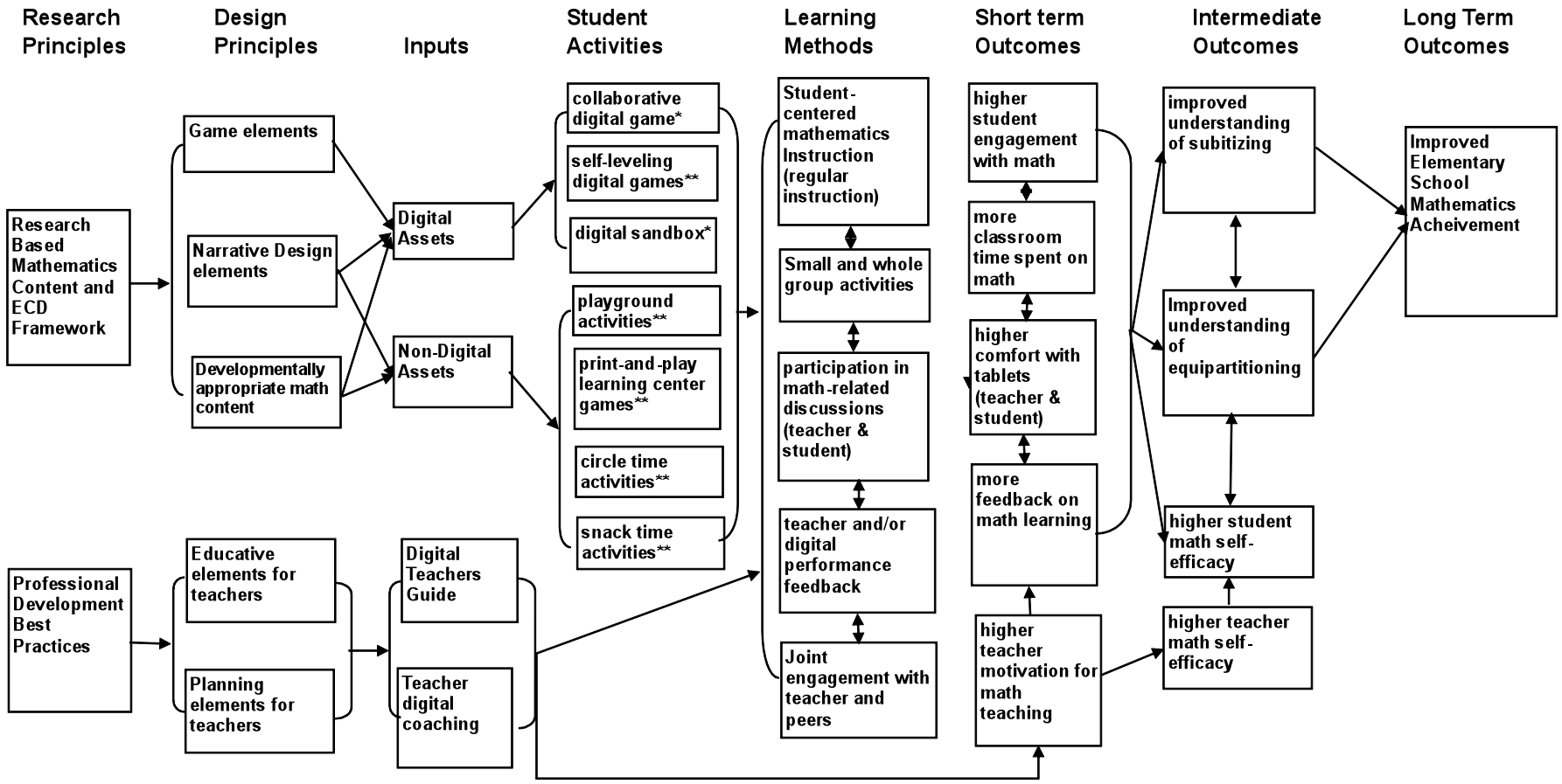
The NGPM team spent the first year rapidly prototyping apps for formative testing in preschool classrooms. Prototypes explored multiple game mechanics, innovative user interfaces, and various approaches to content with the goal of determining the most effective and appealing aspects of interactive tablet games. Testing of each prototype occurred in multiple preschool classrooms and was enacted by both the production and research teams concurrently. This parallel testing led to many rich discussions as the team worked toward its goal of producing apps that are developmentally appropriate, engaging and impactful.

Next Gen Math is exploring various modes of play as well: collaborative play (whether that be simultaneous touch among two children, role play, mentor and student, or turn taking), self-leveling gaming, and sandbox or exploratory play.

The interactive Teacher's Guide gathers real-time data from each child's iPad play and provide teachers with real-time data on each student's progress.

Next Generation Preschool Math is making a significant contribution to the nascent and growing body of formal research on best practices and design principles for the creation of effective educational apps.

Next Generation Preschool Mathematics -- Logic Model



*1 per unit
** 2 per unit

Excerpted from NGPM Annual Report to NSF, Year 1, August 2012

1d. Memo on Joint Media Engagement

Guiding Insights on Joint Media Engagement for NGPM Designers

What is Joint Media Engagement, and why is it important to think about for technology-based curricular materials?

While media presents many strong and unique affordances that support learning, researchers today are keenly aware of the importance of how social interactions influence children's learning from media, and how engaging a media object together can influence the social interaction in a way that supports learning. **Joint Media Engagement (JME)** is the term that researchers have begun to use to describe this type of arrangement.

JME can happen anywhere and at any time when individuals interact with one another while simultaneously attending to a media artifact—for example, a television show, an interactive game, or a traditional book. JME can take many forms including viewing, playing, searching, reading, contributing, and creating (Stevens & Penuel, 2010), and can occur between adults and children or between peers.

Understanding what young children's Joint Media Engagement looks like in its various forms—in schools and in homes, with adults and with peers, with traditional screen media and interactive games—provides critical context for how digital media may be integrated and used in preschool classrooms. Below, we provide a brief review of research literature that speaks to these various dimensions of JME.

Because few studies exist that document patterns of JME with very young children, we have supplemented the design principles and considerations from these studies with research insights on how adults mediate children's home television viewing (often referred to as "co-viewing"). We also highlight JME strategies employed by teachers in media-based preschool curricula that have been shown to improve children's early school readiness skills.

Useful Ideas for NGPM Designers and Researchers

1. Across settings, children often do not have the benefit of an adult guide when engaging with media.
2. Adults can play a key role in extending children's learning through apps and digital games. Design games encourage the child to connect to other experiences in the classroom and in life.
3. Caregivers need support and guidance about engaging with children in learning-focused interactions during media engagement. When adults "co-view" with them, interacting during media viewing in ways that benefit learning are NOT natural.

4. Fit NGPM activities with existing classroom settings and activities so they complement, rather than replace current practices. Advise NGPM teachers to introduce digital games during a time in the school day when an adult is available to check-in with children and provide individual support (e.g., center time)
5. Because children do not necessarily engage deeply with media without support, explicitly highlight the key ideas and problem solving strategies presented in media that children should learn. This could come in the form both of instructions in teacher's guides and voiceover explanations embedded in interactives that children will play without adult support.
6. Design media experiences fit within the broader system of classroom activities to allow teachers to engage children before, during, and after media use in ways that support and augment learning.
7. Professional development is key to preparing adults to actively interact with and scaffold children's media-supported learning. However, workshop trainings may not be sufficient to fully support classroom integration. Providing ongoing tips that promote teacher engagement and discussion, perhaps embedded in media materials or training guides, may help teachers help children get the most out of their use of media use.
8. In the absence of adult scaffolding, true collaboration in digital game play is rare and likely challenging for very young children, but turn-taking appears to come naturally. Games should build upon preschool children's familiarity and comfort with turn structures.
9. With adult support, preschool children can provide important scaffolding for their classmates to help them learn from digital games, even when each child is not actively manipulating the game. Children may be used to playing cooperatively on desktop computers; thus, tablet-based games developed for NGPM should be accompanied with suggestions for teachers in how to foster this same type of collaboration with a smaller-screened technology that does not allow multiple children to take on some of the less active, yet important roles during game play.