Learning Math with *Curious George*: PBS KIDS Transmedia and Digital Learning Games in the Preschool Classroom

A Report to the CPB-PBS Ready To Learn Initiative

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Highlights of the Findings

WestEd conducted a classroom-based study during the summer of 2014 for the CPB-PBS Ready To Learn Initiative in order to investigate children's relatively unmediated use of the *Curious George's Busy Day* transmedia suite (digital games, hands-on learning activities, and video episodes) in supporting preschool children's mathematics learning in the classroom environment. The intervention involved a blended learning experience that took place at learning stations in the preschool classroom. The current study explored the effectiveness of the *Curious George's Busy Day* transmedia suite in supporting preschool children's mathematics learning in the preschool classroom environment. In addition, the study examined the affordances — that is, features and advantages — of transmedia-based learning in the preschool classroom.

Findings Around Children's Knowledge and Skills in Mathematics

- Over the course of the *Curious George* mathematics intervention, children's knowledge of mathematics increased significantly, as measured by selected items from the Test of Early Mathematics Ability, third edition, or TEMA-3 (Pre-test mean = 21.04, Post-test mean = 23.75, $p<0.01$).
- Children showed significant and positive Pre-test and Post-test mean changes on mathematical skills related to number comparison (Pre-test mean = 5.98, Post-test mean = 7.06, $p<0.05$) and informal concepts (Pre-test mean = 0.86, Post-test mean = 1.12, $p<0.05$).
- The results indicated that children with lower pre–TEMA-3 scores gained significantly on numbering (Pre-test mean = 6.24, Post-test mean = 8.20, $p<0.04$), whereas children with higher pre–TEMA-3 scores gained significantly on mathematical skills related to number comparison (Pre-test mean = 7.65, Post-test mean = 9.12, $p<0.02$) and informal concepts (Pre-test mean = 1.38, Post-test mean = 1.77, $p<0.01$).

Affordances of Using Curious George Math in the Preschool Classroom

- Findings suggest the playful and engaging structure and narrative of the transmedia suite were highly motivating for the children. Data analysis suggests that children were highly engaged in all aspects of the suite, including watching the video episodes at home. Teachers felt that the engaging aspects of the materials contributed to children's persistence and positive engagement with the mathematics content in the intervention.
- Data from researchers and teachers suggest that children's self-directed use and free choice in game play led to increased collaborative learning and discourse around mathematics within the classroom.
- The collaborative play fostered by use of the intervention led to additional opportunities for developing children's socio-emotional skills, such as listening and communication, respecting others, and cooperation and sharing.
- By working together on the *Curious George's Busy Day* digital learning games, children had the opportunity to learn digital literacy skills from one another.
- The ability of the digital games to provide hints and scaffolds for struggling children and to adjust game play to easier or more difficult levels of academic content based on children's mastery of that content supported children's self-paced learning and allowed children to practice skills until they had mastered them.

- Teachers found that, by observing their students interacting independently with the games, they were able to increase their knowledge about the children's learning and mathematical development.

Executive Summary

WestEd conducted a classroom-based study for the CPB-PBS Ready To Learn Initiative during the summer of 2014 in order to investigate children's relatively unmediated use of the *Curious George's Busy Day* transmedia suite in supporting preschool children's mathematics learning in the classroom environment. The *Curious George's Busy Day* transmedia suite includes digital games, hands-on learning activities, and video episodes, all featuring Curious George. The suite uses a narrative domain throughout all aspects of its education products and media platforms to engage children and support learning around the mathematics concept of numeracy. The current study explored the effectiveness of the *Curious George's Busy Day* transmedia suite in supporting preschool children's mathematics learning in the preschool classroom environment. In addition, the study examined the affordances (features and advantages) of transmedia-based learning in the preschool classroom. The study included an intervention developed by teachers and researchers that included all aspects of the suite (digital games, hands-on learning activities, and video episodes) and allowed for a relatively unmediated blended learning experience that was integrated into a typical preschool curriculum. The research questions guiding this study were:

1) Does children's self-directed use of the *Curious George's Busy Day* transmedia suite in the preschool classroom lead to gains in preschool children's early mathematical knowledge in the domains of Numbers and Counting and Operations?

2) What are the affordances of the use of the *Curious George's Busy Day* transmedia suite and related education materials in the preschool classroom?

The Study Intervention

The study intervention included 16 digital learning games selected from the *Curious George's Busy Day* transmedia suite, *Curious George's Busy Day* hands-on materials from the PBS KIDS Lab website, three *Curious George* video episodes, and books and other common classroom materials available at the participating intervention preschool. In general, children participating in the study used the selected content with minimal teacher, parent, or researcher mediation. The structure of the intervention built upon the school's current classroom practice of arranging education content into "learning stations," with children moving from learning station to learning station throughout a typical morning in their classroom. In addition, parents were asked to play the *Curious George* video episodes for their children at home during a time when they normally would allow their children to watch television, a DVD, or other video content. Parents were asked to encourage their children to watch the videos at least once over the four-week study period, and children were free to watch the videos as many times as they liked. The intervention, dubbed *Curious George Math* for the purposes of this study, allows for children to interact with *Curious George's Busy Day* mathematics content in the classroom for at least 30 minutes a day twice a week over a four-week period. Children spent at least 60 minutes viewing *Curious George* episodes over the course of the intervention. The intervention focused on two specific mathematics concepts each week that included cardinality, counting, identifying digits, comparing numbers, identifying the number after, and simple addition.

Classroom activities for *Curious George Math* took place at learning stations implemented in three classrooms at the intervention preschool. Before the intervention took place, it was determined that the use of learning stations, in which children move from station to station during unstructured learning time, are a daily activity at the intervention preschool. During the *Curious George Math* intervention, participating children rotated through three learning stations:

- Learning Station 1: A bank of computers where *Curious George's Busy Day* digital learning games were available for exploration
- Learning Station 2: A table with hands-on activities from the *Curious George's Busy Day* section of PBS KIDS Lab and adapted from *Curious George's Busy Day* games
- Learning Station 3: A free play area with a variety of indoor and outdoor classroom activities that changed daily, such as painting, sand table, and imaginative play

During the intervention, teachers moved about the stations and observed student activities. Learning Stations 1 and 2 were specifically designed to allow children to interact with and learn from *Curious George's Busy Day* mathematics content.

Study Methodology

Participants

The target population of the *Curious George Math* preschool study was preschoolers age 3 to 5 years old. Sixty-eight children were recruited from a preschool serving low-income communities in the San Francisco Bay Area and took part in the intervention. Classroom teachers from the preschool were also recruited to participate in the study. Complete pre- and post-assessment data were successfully obtained from 51 children. Participating children's average age was 4.3 years old.

Instruments

Test of Early Mathematics Ability (TEMA-3). The Test of Early Mathematics Ability, third edition, is a test of children's informal and formal mathematics knowledge, and was developed by Western Psychological Services (Ginsburg & Baroody, 2003). The test is designed for use with children ages 3 years and 0 months through 8 years and 11 months. A total of 26 items were selected to measure numbering (e.g., children learning to recognize collections of one or two items and labeling them "one" and "two"), informal concepts (e.g., children demonstrating understanding of informal cardinality rules), number comparisons (e.g., children choosing the larger number), reading and writing numerals (e.g., children reading single-digit numbers), and calculation (e.g., children's mental addition: sums 5 to 9). These items measure the skills that are supported by the 16 *Curious George's Busy Day* games and materials used in this study.

For the purpose of this study, the TEMA-3 experimental score was used to analyze children's mathematics ability. The experimental score is based on selected TEMA-3 items, though each item may contain multiple sub-problems. The total number of selected TEMA-3 items was 26, while the total number of sub-problems was 53. The experimental score is defined as the number of sub-problems scored correct on the selected TEMA-3 items (one point per correct response). Therefore, the experimental score ranged from 0 to 53. The overall reliability of the selected TEMA-3 items was high (KR20 = .94 for pre-assessment and KR20 = .95 for post-assessment).

Classroom Observations. Each day of the study, researchers filled out activity logs to track each student's use of digital learning games, hands-on activities, and other interactions with the intervention content. Researchers verified that the intervention was implemented with fidelity. In addition, researchers recorded their observations of children's behaviors while interacting with *Curious George Math* materials and activities.

Teacher Interviews. At the end of the intervention, each classroom teacher participated in a teacher interview. Teachers were asked to reflect on how the intervention content was incorporated into their regular classroom environment, how their children responded to the content, and whether they felt the content helped to support their children's mathematics learning.

Results

Successful Implementation

- Over the course of the intervention, participation was robust with 49 children (96 percent) playing at least 15 of the 16 *Curious George's Busy Day* digital games, and 45 children (88 percent) participating in five or more of the hands-on mini-lessons.
- Parents reported that they watched the *Curious George* videos at least once with their children at home.

Findings Around Children's Knowledge and Skills in Mathematics

- Over the course of the *Curious George Math* intervention, children's knowledge of mathematics significantly increased, as measured by the selected TEMA-3 items (Pre-test mean = 21.04, Post-test mean = 23.75, $p<0.01$).
- In particular, from pre- to post-test, children showed significant gains on mathematical skills related to number comparison (Pre-test mean = 5.98, Post-test mean = 7.06, $p<0.05$) and informal concepts (Pre-test mean = 0.86, Post-test mean = 1.12, $p<0.05$).
- Researchers further analyzed the data to explore whether the *Curious George Math* intervention helped children with different pre-assessment mathematical skill levels in different ways. The results indicated that children with lower pre–TEMA-3 scores gained significantly on numbering (Pre-test mean = 6.24, Post-test mean = 8.20, $p<0.04$), whereas children with higher pre–TEMA-3 scores gained significantly on mathematical skills related to number comparison (Pre-test mean = 7.65, Post-test mean = 9.12, $p<0.02$) and informal concepts (Pre-test mean = 1.38, Post-test mean = 1.77, $p<0.01$).

Affordances of Using Curious George Math in the Preschool Classroom

A Playful Transmedia Environment Contributed to Student Engagement. Analysis of classroom observation and teacher interview data produced findings that suggest the playful and engaging structure and narrative of the transmedia suite was highly motivating for the children. Observations and teacher reports suggest that children were highly engaged in all aspects of the suite, including watching the video episodes at home. Teachers felt that the engaging aspects of the materials contributed to children's persistence and positive engagement with the mathematics content in the intervention.

Children's Self-Directed Use of* Curious George Math *Led to Collaborative Learning and Classroom Academic Discourse. A major affordance of children's self-directed use of the *Curious George's Busy Day* digital learning games and related education materials in the preschool classroom

was the emergence of children's collaborative learning and academic discourse in the classroom. For the current study, children had agency in every aspect of their learning, from choosing what content to interact with, how they engaged with that content, and how long they wanted to play. Researchers and teachers observed that this free choice often led to increased collaborative learning and discourse around mathematics within the classroom. Researchers and teachers observed daily student discussions and positive interactions around mathematics while at the computer and hands-on learning stations.

Collaborative Learning Interactions Supported Children's Socio-Emotional Learning. The collaborative play fostered by use of the intervention also led to additional opportunities for developing children's socio-emotional skills, such as listening and communication, respecting others, and cooperation and sharing. Socio-emotional learning is a significant component of the preschool curriculum, and teachers reported that children's self-directed use of the *Curious George's Busy Day* activities helped to support this learning.

Collaborative Learning Interactions Supported Children's Digital Literacy Skills. By working together on the *Curious George's Busy Day* digital learning games, children also had the opportunity to learn technological literacy skills from one another. Teachers mentioned that they appreciated this affordance of the intervention; while technological literacy is not part of the kindergarten readiness curriculum, they felt these were important skills for their children to learn.

Curious George Math *Allows for Self-Paced Learning and an Engaging Environment to Practice Skills Repeatedly.* One powerful affordance of game-based learning is the ability of digital games to provide hints and scaffolds for struggling children, and adaptive leveling to adjust game play to easier or more difficult levels of academic content based on children's mastery of that content. Teachers reported that this affordance supported children's self-paced learning and allowed children to practice skills until they had mastered them. Teachers reported they particularly appreciated the aspect of free choice provided to children as they interacted with the digital learning games, and said children very often chose games that challenged them.

Curious George Math *Provides Support for Teachers' Instructional Practice.* One unexpected, but positive, affordance of the *Curious George Math* intervention was the increase in teachers' knowledge around student learning. Teachers found that, like other high-quality lessons they have implemented, by observing their children interacting independently with the *Curious George's Busy Day* digital learning games, they were able to increase their knowledge about their children's learning and mathematical development.

Many of the affordances of *Curious George Math* align with the recommendations for best practices in the use of technology and interactive media in the classroom identified in past research and in a policy statement produced by the National Association for the Education of Young Children (NAEYC) and the Fred Rogers Center (NAEYC, 2012). The findings of the current study support the NAEYC and Fred Rogers Center's assertion that, when implemented appropriately, early child educators may "improve program quality by intentionally leveraging the potential of technology and media for the benefit of every child" (NAEYC, 2012, p. 1).

Learning Math with Curious George: PBS KIDS Transmedia and Digital Learning Games in the Preschool Classroom

As a part of the CPB-PBS Ready To Learn Initiative, PBS KIDS designed and developed a transmedia suite of digital learning games and related education products based on Curious George, the popular character from the PBS KIDS television series and online games. Transmedia, or transmedia storytelling, connotes a technique of representing a narrative or story experience across multiple platforms and formats. The *Curious George's Busy Day* transmedia suite includes digital learning games, hands-on learning activities, and video episodes, all featuring Curious George. The suite uses a narrative domain throughout all aspects of its education products and media platforms to engage children and support learning around the mathematics concept of numeracy. The suite is available for free on the PBS KIDS Lab website and is accessed frequently by teachers, parents, and young children. PBS KIDS Lab (pbskids.org/lab) provides young children access to the newest PBS KIDS digital learning games from the CPB-PBS Ready To Learn Initiative. The site also provides teachers and parents ideas for hands-on activities that support young children's mathematics and literacy learning. The current study explores the effectiveness of the *Curious George's Busy Day* transmedia suite in supporting preschool children's self-directed mathematics learning in the preschool classroom environment.

Growth in Access to Digital Learning Games in Early Childhood

With increased access to game-based and mobile technologies, a growing number of young children are interacting with digital learning games via tablets, mobile phones, hand-held devices, gaming consoles, and computers. In families with children age 8 and under, there has been tremendous growth in ownership of tablet devices, from 8 percent of all families in 2011 to 40 percent in 2013. In addition, the percentage of all children with access to a tablet, smartphone, or other mobile device at home jumped from 52 percent in 2011 to 75 percent in 2013 (Common Sense Media, 2013). At the same time, young children are increasingly accessing digital learning games on computers and gaming consoles (Berson & Berson, 2010; Buckleitner, 2009; Chiong & Shuler, 2010; Common Sense Media, 2013; Couse & Chen, 2010; Lisenbee, 2009).

Digital Learning Games in the Preschool Classroom

Though preschool-age children's use of digital learning games at home has grown significantly in the past several years, growth in the use of digital media in the preschool classroom is recent (Lisenbee, 2009; National Institute for Literacy, 2008; Rideout, Lauricella, & Wartella, 2011; Rosen & Jaruszewicz, 2009). Over the past several years, educators and researchers in the field of early childhood education have debated the advantages and possible dangers of utilizing these technologies in the classroom (AAP, 2011). In order to provide guidance to those working in early childhood education programs, the National Association for the Education of Young Children (NAEYC) and the Fred Rogers Center (FRC) conducted an extensive review of literature on the topic of the use of technology and interactive media in the preschool classroom and issued a policy statement (NAEYC, 2012). The policy statement concludes that: "When the integration of technology and *interactive media* in early childhood programs is built upon solid developmental foundations, and early childhood professionals are aware of both the challenges and the opportunities, educators are positioned to improve program quality by intentionally leveraging the potential of technology and media for the benefit of every child" (p. 1). The statement emphasizes the promise of interactive media, that is, media "designed to facilitate active and creative use by young children and to encourage social

engagement with other children and adults." It contrasts interactive media with non-interactive media that encourages passive viewing and can lead to unhealthy levels of "screen time" (AAP, 2011). The policy statement suggests that the use of technology and interactive media such as digital learning games could be an important instructional feature in a well-designed preschool learning environment.

Types of Digital Learning Games and How They Should Be Used

The NAEYC and FRC policy statement identified several design features that early childhood educators should be aware of when selecting interactive media for use in their classrooms. These include choosing media that are "active, hands-on, engaging, empowering, give the child control, provide adaptive scaffolds to ease the accomplishment of tasks, and are used as one of many options to support children's learning" (p. 6). In addition, the authors suggest that the media should be "playful" and support "co-viewing and co-participation between adults and children and children and their peers" (p. 7), as well as "integrated into the [classroom] environment, curriculum and daily routines" (p. 8). Other recent research studies support these recommendations (Couse & Chen, 2010; Hertz, 2011; Takeuchi, 2011; Technology and Young Children Interest Forum, 2008).

The NAEYC and FRC policy statement concludes by reminding readers that there is a great need for more research to inform inclusion of digital resources in the preschool classroom: "Research is needed to better understand how young children use and learn from technology and interactive media and also to better understand any short- and long-term effects" (NAEYC, 2012, p. 11). The current study addresses the need for research on how young children use and learn from technology and interactive media in the preschool classroom. In particular, it explores the potential for children to learn curriculum-aligned mathematics concepts by interacting with a transmedia suite in a relatively unmediated classroom environment. It also explores how children in a preschool classroom use a transmedia suite of learning materials including digital learning games, hands-on materials, and video episodes.

The Current Study

Researchers conducted a classroom-based study during the summer of 2014 in order to investigate the promise of the *Curious George's Busy Day* transmedia suite in supporting preschool children's self-directed mathematics learning in the classroom environment. In addition, the study examined the affordances (features and advantages) of transmedia-based learning in the preschool classroom. The study included an intervention developed by teachers and researchers that included all aspects of the suite (digital learning games, hands-on activities, and video episodes) and allowed for a relatively unmediated blended learning experience that was integrated into a typical school day at a preschool in the San Francisco Bay Area. The research questions guiding this study were:

> 1) Does children's self-directed use of the *Curious George's Busy Day* transmedia suite in the preschool classroom lead to gains in preschool children's early mathematical knowledge in the domains of Numbers and Counting and Operations?
>
> 2) What are the affordances of the use of the *Curious George's Busy Day* transmedia suite and related education materials in the preschool classroom?

The Intervention

The intervention included 16 digital learning games selected from the *Curious George's Busy Day* transmedia suite, *Curious George's Busy Day* hands-on materials from the PBS KIDS Lab website, 3 *Curious George* video episodes, and books and other common classroom materials available at the participating intervention preschool. In general, children participating in the study used the selected content with minimal teacher, parent, or researcher mediation. The structure of the intervention built upon the school's current classroom practice of arranging education content into "learning stations," with children moving from learning station to learning station throughout a typical morning in their classroom. In addition, parents were asked to play the *Curious George* video episodes for their children at home during a time when they normally would allow their children to watch television, a DVD, or other video content. Parents were asked to encourage their children to watch the videos at least once over the four-week study period, and children were free to watch each video as many times as they liked. The intervention, dubbed *Curious George Math* for the purposes of this study, allows for children to interact with *Curious George's Busy Day* mathematics content in the classroom for at least 30 minutes a day twice a week over a four-week period. Children spent at least 60 minutes viewing *Curious George* episodes over the course of the intervention. The intervention focused on two specific mathematics concepts each week. Twice each week, children interacted with *Curious George Math* activities and materials related to a specific mathematics concept. Table 1 shows the mathematics concepts presented to children each week during the *Curious George Math* intervention. For each concept, children interacted with related digital learning games and hands-on activities.

Table 1. Mathematics content included in the *Curious George Math* intervention.

Mathematics Concepts	
Week 1	
Days 1–2 Days 3–4	Cardinality Counting
Week 2	
Days 1–2 Days 3–4	Identifying Digits Comparing Numbers
Week 3	
Days 1–2 Days 3–4	Identifying the Number After Simple Addition
Week 4	
Days 1–4	Review

Curious George Math: Classroom Activities

Classroom activities for *Curious George Math* took place at learning stations implemented in three classrooms at the intervention preschool. Before the intervention took place, it was determined that the use of learning stations, in which children move from station to station during unstructured learning time, were a daily activity at the intervention preschool. During the *Curious George Math* intervention, participating children rotated through three learning stations:

- Learning Station 1: A bank of computers where *Curious George's Busy Day* digital learning games were available for exploration
- Learning Station 2: A table with hands-on activities from the *Curious George's Busy Day* section of PBS KIDS Lab and adapted from *Curious George's Busy Day* games
- Learning Station 3: A free play area with a variety of indoor and outdoor classroom activities that changed daily, such as painting, sand table, and imaginative play

During the intervention, teachers moved about the stations and observed student activities. Learning Stations 1 and 2 were specifically designed to allow children to interact with and learn from *Curious George's Busy Day* mathematics content. A description of Learning Stations 1 and 2 follows.

Learning Station 1: Digital Learning Games

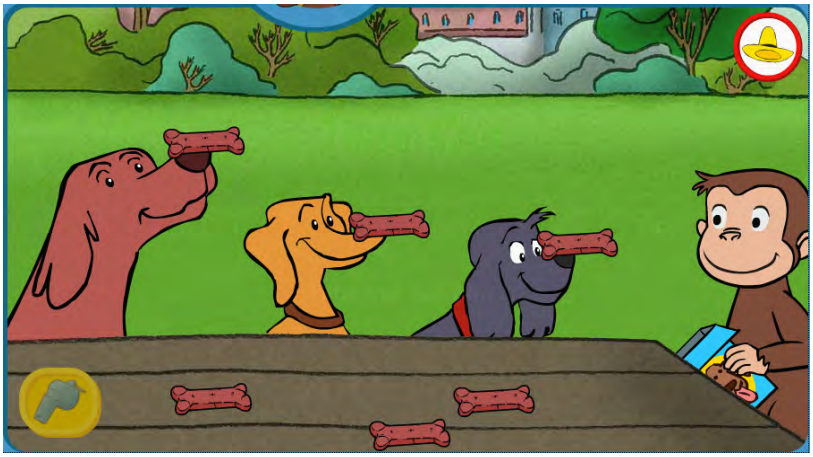
Learning Station 1 featured the 16 digital learning games from the *Curious George's Busy Day* transmedia suite. Each digital game is colorful, engaging, and includes elements of play. Each game presents a mathematics concept to children, allows for exploration and practice of the concept, and moves to more difficult levels of the concept when the children achieve mastery of easier levels. Table 2 below lists each of the 16 games, along with the learning goals and mathematics concepts addressed in each game.

Table 2. Description of digital learning games from the *Curious George's Busy Day* transmedia suite.

GAME	LEARNING GOALS
Meatball Launcher	Count 1 to 5 objects upon request
Flower Garden	Count by ones up to 20
Bubble Pop	Count aloud by ones up to 50
Bunny Ride	Count on by ones from a number other than 1
Blast Off	Count backward from 10 to 0
High Fives	Count by fives up to 200
Count with Allie	Count and represent quantities in different ways
Hide & Seek	Identify numbers from 0–10 as numerals, words, and quantities
Fair Shares	Count and separate items into equal groups
Monkey Jump	Count up to 40 with the understanding that each number is one more than the last
Hat Grab	Use a graph to compare numbers
Bug Catcher	Count and compare two sets of numbers to determine which is greater
Apple Picking	Use number lines to identify missing numbers up to 19
Train Station	Add and decompose numbers up to a total of 10
Museum of Tens	Add objects to complete a set of 10
Ribbit	Recognize and use the addition and subtraction signs

Figure 1 shows the digital game *Fair Shares*, which teaches children ages 3 to 5 years to share up to 12 objects equally among two or three groups. In the level of the game shown, children are asked to share six dog bones equally among three dogs.

Figure 1. Screenshot from the *Fair Shares* digital learning game.



Learning Station 1 featured two or three computers (either desktop computers specifically designed for preschool use or Chromebook laptops). During each day of the intervention, groups of four to five children rotated through Learning Station 1, with each group spending approximately 15 minutes interacting with the digital learning games. Children were encouraged to use the computers in pairs, though some children preferred to work alone. While visiting Learning Station 1, children always had the choice to work in pairs or work alone, move to a different computer to observe or help other children, change seats with their partner to take turns using the mouse, or switch activities by moving to Learning Station 3 (free play area).

When children arrived at Learning Station 1, researchers would suggest two or three "featured games" from the *Curious George's Busy Day* suite for the children to play. The featured games were aligned with the mathematics content highlighted in the hands-on learning activities available at Learning Station 2 on that day. For instance, a child might play the digital game, *Hide & Seek*, which reviews concepts of identifying numbers as numerals, words, and quantities, on the same day that she engages in a hands-on activity using number cards[1] at Learning Station 2. Children were encouraged, but not required, to play each of the featured digital learning games at least once during their time at Learning Station 1. However, children always had the choice of which games to play within the *Curious George's Busy Day* transmedia suite and how long to play each game. Children were free to switch between different *Curious George's Busy Day* games while they were at Learning Station 1.

Role of Researchers at Learning Station 1

Researchers provided minimal guidance while children interacted with digital learning games at Learning Station 1. Researchers followed an established facilitation protocol that clearly outlined what type of assistance could be provided to children (e.g., guidance related to understanding game mechanics, but not

[1] Number cards are a set of cards printed with the digits 1–10, the words *one* through *ten*, and illustrations of quantities of objects from 1–10. This activity was adapted from PBS KIDS Lab (http://pbskids.org/lab/activity/numbercards).

assistance with a game's mathematical content) and how often this assistance could be provided, in order to encourage the most independent use of the *Curious George's Busy Day* mathematics content by children.

Researchers' primary role at Learning Station 1 was that of observer. However, researchers did ensure that the day's featured games were pre-loaded on the computers when children first arrived at the learning station, and also ensured that children only played games within the *Curious George's Busy Day* suite. Researchers also assisted with any technical troubleshooting, such as computer and Internet problems or helping children with technical-related game issues (such as clicking the "Allow" button for games that required use of the webcam). In contrast, researchers did not provide any content-related or game-related assistance to children (with one exception being if a student did not have a partner at the computer and if that solo student was struggling with the game for a sustained period of time). Researchers occasionally assisted with behavior or classroom management issues at Learning Station 1, such as sharing and getting equal play time on the computer.

Learning Station 2: Hands-On Learning Activities

At Learning Station 2, children were invited to interact with hands-on activities from the *Curious George's Busy Day* section of PBS KIDS Lab and adapted from the *Curious George's Busy Day* games, as well as with books and other common classroom materials available at the intervention preschool. Materials were organized into informal mini-lessons based on *Curious George's Busy Day* mathematics content. Engagement with the activities at Learning Station 2 was optional and flexible. For instance, children could interact with content, help a friend, sit and watch, or choose to do another activity such as color, build with available materials, or leave the table and move to Learning Station 3 (free play area). A researcher with teaching experience sat at Learning Station 2 and invited children to engage in the mini-lessons.

Each week of the four-week intervention focused on two specific mathematics concepts. For each mathematics concept, children had the opportunity to engage with a hands-on learning activity and with two or three digital games from the *Curious George's Busy Day* suite. The hands-on learning activities are described in detail in Table 3 below. The appendix includes examples of materials used at the learning station each week.

Table 3. Description of hands-on learning activities and related digital learning games.

ACTIVITY	CONCEPT	DESCRIPTION	*Curious George's Busy Day* Digital Learning Games
1	Cardinality	Children engaged with the book, *Chrysanthemum*, and counted the number of letters in their own name using linking plastic cubes.	*Count with Allie* *Fair Shares* *Ribbit*
2	Counting	Children engaged with the book, *Bunches of Buttons*, and used groups of buttons to count by 10s.	*High Fives* *Blast Off* *Bunny Ride*
3	Identifying Digits	Children used number cards to match numbers using digits, words, and quantities.	*Hide & Seek* *Bubble Pop*
4	Comparing Numbers	Children engaged with the book, *Just Enough Carrots*. Children were each given a playing card and were asked to compare the value of their card (more, same, fewer) to their classmates' cards.	*Bug Catcher* *Hat Grab* *Monkey Jump*
5	Identifying the Number After	Children completed the "Apple Picking" worksheet from PBS KIDS Lab as a guided small group activity. Children also played with number sequencing puzzles.	*Apple Picking* *Flower Garden* *Meatball Launcher*
6	Simple Addition	Children engaged with the book, *Quack and Count*. Children used a dough mat and sets of beans to create simple addition sentences.	*Train Station* *Museum of Tens*

A Typical Morning During the *Curious George Math* Intervention

A typical morning during the intervention began with children arriving at the preschool early in the morning. After a few hours of independent playtime, teachers gathered the children for "circle time," when the teacher would conduct a whole group welcome and classroom activities. After circle time, the teacher reminded children that they would be interacting with *Curious George Math* activities on that day. The teacher then divided the children into groups that rotated through the learning stations.

One group of children went to Learning Station 1 to interact with the digital learning games, another group went to Learning Station 2 to experience the day's hands-on learning activities, and another group went to Learning Station 3 (free play area with a variety of classroom activities). The groups remained at these stations for approximately 15 minutes, and then the groups rotated stations (e.g., the children at Learning Station 1 would move to Learning Station 2). The groups then engaged with the games and activities at their new station for 15 minutes.

Curious George Math: Home Activities

Children watched three *Curious George* video episodes at home at least once over the course of the intervention. Video episodes were delivered via DVDs to all families whose children were participating in

the study. Teachers and the director of the school communicated with parents via letter and verbal reminders, requesting that parents play each episode at least once during the study period. Parents were asked to play the *Curious George* video episodes at their child's request at a time when they normally would allow their children to watch television, a DVD, or other video content. The three video episodes provided to families are described below.

> Episode 1: *Bunny Hunt*. This video focuses on counting and is related to the narrative and mathematics content in the *Bunny Ride* game. In this video, Curious George looks for bunnies that are on the loose, and children practice counting from 1 to 7.
>
> Episode 2: *Rocket Ride*. This video focuses on counting backward and is related to the narrative and content in the *Blast Off* game. In this video, Curious George rides a rocket to bring food to a space station, and children practice counting backward from 10 to 0.
>
> Episode 3: *Shutter Monkey*. This video focuses on shapes. In this video, Curious George helps a friend by taking pictures for a photography contest and children learn about shapes, including triangles, circles, and squares.

Study Design and Methodology

The study explored whether the relatively unmediated use of 16 digital learning games selected from the *Curious George's Busy Day* transmedia suite, *Curious George's Busy Day* hands-on materials from the PBS KIDS Lab website, three *Curious George* video episodes, and books and other common classroom materials available at the participating intervention preschool impacted preschool children's early mathematics abilities. In addition, the study examined the affordances (features and advantages) of transmedia-based learning in the preschool classroom. The study addressed 1) the intervention's impact on children's early mathematical knowledge in the domains of Numbers and Counting and Operations, and 2) the affordances of the suite and its related education materials in the preschool classroom.

Participants

The target population of the *Curious George Math* preschool study was preschoolers ages 3 to 5 years old. Sixty-eight children were recruited from a preschool serving low-income communities in the San Francisco Bay Area and took part in the intervention. Classroom teachers from the preschool were also recruited to participate in the study. Complete pre- and post-assessment data were successfully obtained from 51 children. Participating children's average age was 4.3 years old. Over the course of the intervention, participation was robust, with 49 children (96 percent) playing at least 15 of the 16 *Curious George's Busy Day* digital games, and 45 children (88 percent) participating in five or more of the hands-on mini-lessons.

Instruments

Test of Early Mathematics Ability (TEMA-3)

The Test of Early Mathematics Ability, third edition, is a test of children's informal and formal mathematics knowledge, and was developed by Western Psychological Services (Ginsburg & Baroody, 2003). The test is designed for use with children ages 3 years and 0 months through 8 years and 11 months. A total of 26 items were selected to measure numbering (e.g., children learning to recognize collections of one or two items and labeling them "one" and "two"), informal concepts (e.g., children demonstrating understanding of

informal cardinality rules), number comparisons (e.g., children choosing the larger number), reading and writing numerals (e.g., children reading single-digit numbers), and calculation (e.g., children's mental addition: sums 5 to 9). These items measure the skills that are supported by the 16 *Curious George's Busy Day* games and materials used in this study.

For the purpose of this study, the TEMA-3 experimental score was used to analyze children's mathematics ability. The experimental score is based on selected TEMA-3 items, though each item may contain multiple sub-problems. The total number of selected TEMA-3 items was 26, while the total number of sub-problems was 53. The experimental score is defined as the number of sub-problems scored correct on the selected TEMA-3 items (one point per correct response). Therefore, the experimental score ranged from 0 to 53. The overall reliability of the selected TEMA-3 items was high (KR20 = .94 for pre-assessment and KR20 = .95 for post-assessment).

Classroom Observations

Each day of the study, researchers filled out activity logs to track each student's use of digital learning games, hands-on activities, and other interactions with the intervention content. Researchers verified that the intervention was implemented with fidelity. In addition, researchers recorded their observations of children's behaviors while interacting with *Curious George Math* materials and activities.

Teacher Interviews

At the end of the intervention, each classroom teacher participated in a teacher interview. Teachers were asked to reflect on how the intervention content was incorporated into their regular classroom environment, how their children responded to the content, and whether they felt the content helped to support their children's mathematics learning.

Student Demographic Data

Researchers collected student demographic data, including gender, age, and language preference, from children's classroom teachers.

Data Analysis

A paired t-test was used to analyze changes from pre- to post-test on student outcomes as measured by the TEMA-3. Qualitative data from the researcher observation logs and teacher interviews were analyzed using grounded theory, or constant comparative analysis (Strauss & Corbin, 1998). In an initial data reduction approach, qualitative data were reviewed and assigned categories of meaning (open coding). Then, these categories along with quantitative data results were reviewed for causal linkages and non-causal relationships related to the central phenomenon (axial coding), which allowed researchers to develop a "story" that connects the categories (selective coding) and, finally, posit hypotheses or theoretical propositions.

Results

Over the course of the intervention, participation was robust with 49 children (96 percent) playing at least 15 of the 16 *Curious George's Busy Day* digital games, and 45 children (88 percent) participating in five or

more of the hands-on mini-lessons. In addition, parents reported that they watched the *Curious George* videos at least once with their children at home.

Children's Knowledge and Skills in Mathematics: Findings from the TEMA-3

Over the course of the *Curious George Math* intervention, children's knowledge of mathematics increased significantly, as measured by the selected TEMA-3 items (Pre-test mean = 21.04, Post-test mean = 23.75, $p<0.01$). In particular, children showed significant and positive pre- and post-changes on mathematical skills related to number comparison (Pre-test mean = 5.98, Post-test mean = 7.06, $p<0.05$) and informal concepts (Pre-test mean = 0.86, Post-test mean = 1.12, $p<0.05$) (Table 4).

Researchers further analyzed the data to explore whether the *Curious George Math* intervention helped children with different pre-assessment mathematical skill levels in different ways. The results indicated that children with lower pre-assessment TEMA-3 scores gained significantly on numbering (Pre-test mean = 6.24, Post-test mean = 8.20, $p<0.04$), whereas children with higher pre-assessment TEMA-3 scores gained significantly on mathematical skills related to number comparison (Pre-test mean = 7.65, Post-test mean = 9.12, $p<0.02$) and informal concepts (Pre-test mean = 1.38, Post-test mean = 1.77, $p<0.01$) (Table 4).

Table 4. Gains in children's early mathematical knowledge as measured by the TEMA-3.

Sample	Measure	Mean (SD)		*t*	*df*	*p-value*
		Pre	Post			
Entire Sample (N=51)	Selected TEMA-3 (51 problems) – Overall	21.04 (10.79)	23.75 (11.43)	-3.20**	50	0.01
	Selected TEMA-3 – Numbering (23 problems)	10.67 (5.26)	11.61 (5.21)	-1.80	50	0.08
	Selected TEMA-3 – Comparisons (14 problems)	5.98 (3.44)	7.06 (3.77)	-2.50*	50	0.02
	Selected TEMA-3 – Informal Concepts (4 problems)	0.86 (0.94)	1.12 (0.95)	-2.64*	50	0.01
	Selected TEMA-3 – Calculation (3 problems)	0.47 (0.81)	0.55 (0.73)	-0.66	50	0.50
	Selected TEMA-3 – Numeral Literacy (9 problems)	3.06 (2.67)	3.41 (2.71)	-1.63	50	0.11
Children with Lower Pre-TEMA-3 Scores (N=25)	Selected TEMA-3 (51 problems) – Overall	12.00 (3.75)	15.28 (8.20)	-2.20*	24	0.04
	Selected TEMA-3 – Numbering (23 problems)	6.24 (2.33)	8.20 (4.64)	-2.18*	24	0.04
	Selected TEMA-3 – Comparisons (14 problems)	4.24 (1.98)	4.92 (2.94)	-1.06	24	0.29
	Selected TEMA-3 – Informal Concepts (4 problems)	0.32 (0.69)	0.44 (0.77)	-0.90	24	0.38
	Selected TEMA-3 – Calculation (3 problems)	0.16 (0.47)	0.12 (0.44)	0.30	24	0.77
	Selected TEMA-3 – Numeral Literacy (9 problems)	1.04 (1.78)	1.60 (2.21)	-1.83	24	0.08
Children with Higher Pre-TEMA-3 Scores (N=26)	Selected TEMA-3 (51 problems) – Overall	29.73 (7.67)	31.88 (7.50)	-2.51*	25	0.02
	Selected TEMA-3 – Numbering (23 problems)	14.92 (3.42)	14.88 (3.30)	0.08	25	0.94
	Selected TEMA-3 – Comparisons (14 problems)	7.65 (3.74)	9.12 (3.34)	-2.51*	25	0.02
	Selected TEMA-3 – Informal Concepts (4 problems)	1.38 (0.85)	1.77 (0.59)	-2.81**	25	0.01
	Selected TEMA-3 – Calculation (3 problems)	0.77 (0.95)	0.96 (0.72)	-1.00	25	0.33
	Selected TEMA-3 – Numeral Literacy (9 problems)	5.00 (1.81)	5.14 (1.87)	-0.50	25	0.62

** Significantly different from zero at the .05 level, two-tailed test.*

*** Significantly different from zero at the .01 level, two-tailed test.*

Children's Knowledge and Skills in Mathematics: Findings from Qualitative Data

Analysis of qualitative data from classroom observations and teacher interviews produced findings that shed light on factors that may have contributed to gains in children's mathematical knowledge. In particular, the data suggest that the intervention is appropriate for the preschool classroom and supports mathematics learning.

Teachers commented on the quality, content, and structure of the *Curious George Math* intervention:

> I like the fact that all the activities are age-appropriate, and very developmentally appropriate as well.
>
> Having the PBS games, they're learning on their own. You're doing patterning, and you're doing what [number] is missing, and you're doing the sequence.
>
> That is how they usually learn. So the more [they] master, the more review they're getting. The more learning content they are absorbing.

Teachers and researchers observed children demonstrating their mathematics learning. The teachers said:

> I think the games were good. They're counting and they're saying their numbers. [Children] really like them, and they are learning, too.
>
> They're learning numbers. I see them learning how to do the association with the word and the number picture, the actual number, and the quantity.

The following vignettes captured by the researchers illustrate children demonstrating and sharing their math knowledge while engaging with the *Curious George's Busy Day* games:

> Two girls are playing *Fair Shares* and are trying to divide four dog treats between two dogs. "Okay, now give it to the other one," Girl 1 says to Girl 2. Girl 2, who is controlling the mouse, moves a third bone to the dog's nose, which is not correct. "They're going to say, 'That's not fair,'" Girl 1 reminds her. Before pressing the whistle to submit her answer, Girl 2 instead moves a bone over from the first dog to the second dog, giving each dog two treats. "I'm putting two," Girl 2 says. The two girls dance together when the Man in the Yellow Hat tells them, "Great Job!"
>
> A little girl is helping her younger classmate play *Meatball Launcher*. The younger classmate keeps piling the plate as high as it will go with meatballs until the game dumps the meatballs off the plate and tells him, "That's too many." The little girl coaches him by saying, "You want three," as she shows him three fingers held close to his face. "Count with me," she says. "One . . ." The boy repeats, "One . . .," while clicking once to add a meatball. Then together they count, "Two, . . . three." The girl then says, "That's enough! Now click on the bell!" When the boy is successful, they both pump two fists in the air and cheer. "Good job," the little girl tells the boy. "Let's do it again!"

Findings Related to Study Research Question 2

Qualitative data analysis was also used to analyze qualitative data from classroom observations and teacher interviews in order to address the study's second research question:

> 2) What are the affordances of the use of the *Curious George's Busy Day* transmedia suite and related education materials in the preschool classroom?

The qualitative data suggest that *Curious George Math* brought a number of affordances to the preschool classroom that contributed to a rich learning environment. These affordances include 1) playful and

engaging transmedia learning content, 2) digital learning games that allow for collaborative learning and academic discourse, and 3) adaptive scaffolding and leveling to support self-paced learning. The collaborative learning fostered by use of the intervention also led to additional opportunities for developing children's socio-emotional skills and children's digital literacy skills. In addition, it was found that *Curious George Math* could be integrated into preschool curriculum and daily routines and support teachers' instructional practice.

A Playful Transmedia Environment Contributed to Student Engagement

The playful and engaging structure and narrative of the transmedia suite was highly motivating for the children. Observations and teacher reports suggest that children were highly engaged in all aspects of the suite, including watching the video episodes at home. Teachers felt that the engaging aspects of the materials contributed to children's persistence and positive engagement with the mathematics content in the intervention. Teachers commented:

> I liked the games and . . . the children loved the games.

> The kids love it and they learn from it, and they don't really know that they're learning because they're having so much fun. But they are learning, because I see some of them counting.

Children's Self-Directed Use of Curious George Math *Supported Collaborative Learning and Classroom Academic Discourse*

A major affordance of children's self-directed use of the *Curious George's Busy Day* digital learning games and related education materials in the preschool classroom was the emergence of children's collaborative learning and academic discourse in the classroom. In the current study, children had free choice and agency in every aspect of their learning, from choosing what content to interact with, how they wanted to engage with that content, and how long they wanted to play. Researchers and teachers observed that free choice led to increased collaborative learning and discourse around mathematics.

Almost all children engaged in collaborative learning while at the computer and hands-on learning stations. The grouping of children was often fluid at the stations, with children switching among different pairings, and with small groups sometimes collaborating together on one game. This often created the opportunity for children of mixed ability levels or mixed ages to work together, or for children with a strong working dynamic to play through the games together. Researchers and teachers observed daily student discussions and positive interactions around mathematics while at the computer and hands-on learning stations. One teacher commented:

> I love the fact that you have the dyad system, where the buddy helps another person. That seems to be helping because they learn from each other.

Collaborative Learning Supported Children's Socio-Emotional Learning

Socio-emotional learning is a significant component of the preschool curriculum, and preschool teachers stated that developing socio-emotional skills in their children, such as listening and communication, respecting others, and cooperation and sharing, is a major goal in their classrooms. Teachers reported that children's collaborative play and self-directed use of the *Curious George's Busy Day* activities helped to support this learning. One preschool teacher recalled and reflected on an anecdote from her classroom during the study:

> I love the way [the children are paired up]. Yesterday I noticed I had two kids . . . playing the apple game, and they said, "Okay, what comes after two?" One kid didn't know, but the other kid—who is actually the same age as him, but at a different level of advancement—he goes, "No, it's three. Three comes next!" And the kid was able to get that help from a peer instead of us saying it. [Working with adults,] they'll be more critical, or they'll feel like we're criticizing them. Then they feel like they don't want to do it anymore. So when a peer is doing it, they want to learn more because they want to please them . . . We're learning from each other. You know, sometimes it's draining for adults to say the same thing. But the kids have a way of saying it in [a] way where they don't have expectations. We [adults] have expectations. So then we get disappointed. And then the kids don't want to do it. But peers, they're not like that. They're like, Okay, it's okay, let me help you again. Let's do it again, let's do it together. And these kids are building empathy by just doing that. And they feel empowered that they're helping each other.

Similarly, another teacher commented on the socio-emotional learning that occurred in her classroom as a result of using the *Curious George's Busy Day* digital learning games:

> They did learn some things. It's not just math, I think they are learning also how to share the computer, because some of them had a really hard time sitting with somebody else. So when they're sitting and we [say], "You need to be really patient," but they [say], "It's my turn!" We [say], "No. They're staying five minutes and then it's your turn." . . . So they are being a little bit more patient, I think. They learned how to share the computer.

Collaborative Learning Supported Children's Digital Literacy Skills

By working together on the *Curious George's Busy Day* digital learning games, children also had the opportunity to learn digital literacy skills from one another. Teachers mentioned that they appreciated this affordance of the intervention because digital literacy is not part of the kindergarten readiness curriculum, but they felt it was an important skill for their children to learn.

> Because teaching . . . with technology and learning styles are changing in elementary schools [with the adoption of the Common Core State Standards], there needs to be something happening [with technology] in the preschool setting, where there should be a connection, and it goes on to when they go to kindergarten. There should be exposure before. That is my opinion.

At the start of the intervention, children in the study classrooms had a range of technology abilities, with respect to controlling a computer mouse and navigating through programs and websites on the computer. One preschool teacher described the technological needs of children in her class:

> I've noticed some of the kids don't know how to use the mouse, and other technical devices, especially the younger kids who have transitioned to our classroom. With those kids, this is a new experience, new exposure. They don't know how to use a mouse, so you have to help them.

Researchers observed that children under the age of 3.5 years tended to have more difficulty with controlling the computer mouse than older children. However, because children were allowed to partner with other classmates during game play, researchers observed that some mixed-age pairings began to form between younger and older children. Researchers observed that some younger children were content to contribute to game play by pointing to the computer screen, while older children might control the mouse. In other instances, researchers observed older children physically helping younger children by placing their hands on the computer mouse together and guiding the mouse's movement. The following vignette illustrates this type of collaboration between two preschool boys:

> Boy 1 and Boy 2 are playing the *Curious George's Busy Day* digital learning games at separate computer stations. Boy 1 is playing *Hide & Seek* and is struggling with controlling the mouse, while Boy 2 quickly clicks through several games in a matter of minutes. When Boy 2 looks over and sees that Boy 1 is stuck on the first level of the game, he comments that "The game is scary," because there is a lion on the screen. "Let me help you," Boy 2 says. "Yeah," Boy 1 responds, "I need a buddy." Boy 2 moves over to Boy 1's computer station and the two begin to work through the levels of *Hide & Seek* together, with Boy 1 pointing where to click on the screen, and Boy 2 controlling the mouse.
>
> When the two boys tire of playing *Hide & Seek*, they play other games together. The boys count down together from the number three in *Blast Off* and laugh together when the dogs flip their treats in *Fair Shares*. When prompted, Boy 2 shares the mouse with Boy 1. At one point, when Boy 1 is having difficulty with the mouse, Boy 2 places his hand over Boy 1's hand to gently guide it. After about five minutes, the boys decide to play together on the other computer that Boy 2 had previously been working on by himself; there's no questioning or negotiation about this. It is clear that they would rather enjoy playing the games together and sharing turns than play alone.

Self-Paced Learning and an Engaging Environment to Practice Skills

One powerful affordance of game-based learning is the ability of digital games to provide hints and scaffolds for struggling children and adaptive leveling to adjust game play to easier or more difficult levels of academic content based on children's mastery of that content. Teachers reported that this affordance in the *Curious George's Busy Day* games supported children's self-paced learning and allowed children to practice skills until they had mastered them. Teachers reported they particularly appreciated the aspect of free choice provided to children as they interacted with the digital learning games, saying children very often chose games that challenged them. Several teachers commented on the affordance of self-paced learning that the intervention brought to the classroom:

> There's a lot of opportunity within the games to level up.
>
> This is the way they master things [content]. If they like something, they are going to play it over and over until they master it. Once they master it, they want to go to the next game. That's how they learn. The more they play, the more they practice and master.
>
> When I tell them, "This is the way it has to be," learning becomes teacher directed versus self-directed. I want them to feel like they are learning, but at their own pace. They are exploring and learning. It's not like a typical learning setting; they are exploring, and they are going to learn even more now.

In addition, teachers said opportunities for self-paced learning and the adaptive leveling of the digital games were helpful for children with different abilities and learning styles.

> One child has less self-esteem and [was quiet during group instruction]. I felt like [the intervention] was really good for him. It was beneficial big time for him [to learn at his own pace]. I wish that he could have had the PBS [program] before. But some exposure is better than no exposure.
>
> I like the fact that children are given a lot of choices because it is good for the brain to work in different ways. Left brain, right brain, different children work in different ways. We have a lot of kids with special needs . . . and they really connect to the games.
>
> I've noticed with one of my boys, 1 to 10 was too [rudimentary] for him. [He] found a game that was 1 to 20 and beyond. He was more challenged. I like that they have different varieties of games in PBS.

Support for Teachers' Instructional Practice

One unexpected but positive affordance of the *Curious George Math* intervention was the increase in teachers' knowledge about student learning. Teachers found that, like other high-quality lessons they have implemented, by observing their children interacting independently with the *Curious George's Busy Day* digital learning games, they were able to increase their knowledge of their children's learning and mathematical development. One teacher reflected on the opportunity to observe children's progress.

> I get to observe and see where they're at. If they have moved forward, or if they are staying behind, or if should I help them, and things like that. So it helps me just observe and evaluate them. But I saw some of them that [before the observation] I thought they didn't know how to count. They were counting, and knew their colors and I was like, "Oh, wow! Okay. So they know!"

One teacher was also surprised to find that she herself learned about mathematics pedagogy from observing her children playing with the *Curious George's Busy Day* digital learning games. She realized that she did not often emphasize the difference between counting and cardinality in her classroom. By hearing the types of feedback and questions that are presented to the children in the digital learning games, the teacher realized that she would often ask her children to count objects, but that she would not then follow up by asking them, "How many objects did you count?" The teacher realized this important distinction by watching her children's interactions with the games and activities. The teacher also recounted another teaching strategy she observed from the game *Blast Off*:

> Another thing was the counting backwards. I think on the counting back, I never asked them to count back. I never asked them. But I sing the song, "5, 4, 3, 2, 1, 0." But I have never asked the children at this age to count backwards. So I am learning a little bit too.

Conclusion

Young children are increasingly interacting with technology and interactive media via tablets, mobile phones, hand-held devices, gaming consoles, and computers. The use of these technologies along with interactive education media is new to the preschool classroom. Early research suggests that interactive education media, including digital learning games, can be a useful instructional tool for teachers in the preschool classroom.

Results of this CPB-PBS Ready To Learn study suggest that, over the course of the intervention (*Curious George Math*), children's knowledge in mathematics increased significantly, as measured by the TEMA-3. In particular, children showed significant and positive pre- and post-assessment gains in mathematical skills related to number comparison and informal concepts. In addition, data from classroom observations and teacher interviews suggest that the intervention brought a number of affordances to the preschool learning environment. These affordances include:

- A playful, engaging learning environment
- Collaborative learning and academic discourse
- Adaptive scaffolding and leveling to support self-paced learning
- Opportunities for developing children's socio-emotional skills
- Opportunities for developing children's digital literacy skills
- Integration into the curriculum and daily routines

These affordances align with many of the recommendations for best practices in the use of technology and interactive media in the classroom identified in past research and in the NAEYC and the FRC policy statement (NAEYC, 2012). The study's findings support the policy statement's assertion that, when implemented appropriately, early child educators may "improve program quality by intentionally leveraging the potential of technology and media for the benefit of every child" (NAEYC 2012, p. 1).

The Need for Teacher Professional Development for Transmedia Learning

One topic to consider when expanding the use of blended learning environments in preschool classrooms is teachers' capacity to effectively design and use these environments. Teachers in the current study said they felt that the *Curious George Math* intervention was a useful instructional tool to enhance mathematics instruction in their classrooms.

Teachers reported that the intervention was feasible for implementation during their school day and that they would like to implement the intervention on their own.

> I think having this concept [the intervention] is great. And I think if I had a consistent time, say like "PBS's Math Time," kids could go there 10 minutes a day. Something like that [would be useful].

However, teachers reported they would like professional development to learn how to best deliver instruction effectively using technology. In addition, the teachers mentioned they would need more access to technology in order to use all of the intervention materials.

> Not everyone is tech savvy. A lot of the teachers—you know, . . . we have teachers from different generations and they are scared and they are afraid to do things. But I think if they had some kind of training and a computer accessible for different ages and we could use it any time we want, we could figure out as a group how we're going to implement it. But we need to have some kind of technical support.

> [Email] that's the only time we use [technology]. We don't actually use it in a game way like we do now. All of our stuff is hands-on. That's what we do with our [teaching and] learning. Because, we are not trained for [using technology]. I would like to get some training so I could use some of the free tools available to us.

Discussion

Research has shown that early mathematics ability is a strong predictor of later mathematics and overall academic achievement (Burchinal et al., 2011; Duncan et al., 2007; Jordan, Kaplan, Ramineni, & Locumiak, 2009), and that children in low-income families enter kindergarten with significantly fewer mathematics competencies than their more affluent peers (Arnold, Fisher, Doctoroff, & Dobbs, 2002; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006; National Research Council and Committee on Early Childhood Mathematics, 2009; Klein, Starkey, Clements, & Sarama, 2007). In order to prepare all children to be successful in kindergarten and beyond, it is important to identify models and mechanisms to improve early mathematics competencies for children in low-income families. As digital technologies become more accessible to preschools serving low-income families, it is important to consider how access to these technologies can support early mathematics learning. The current study suggests that one model, focused on self-directed learning in a blended environment, shows promise toward supporting early mathematics

achievement for children in preschools serving low-income families. Additionally, the current study sheds light on a topic of increasing importance: the use of technology and interactive media in the preschool classroom. The intervention in this CPB-PBS Ready To Learn study included high-quality PBS KIDS transmedia content in a blended learning environment. The intervention supported age-appropriate mathematics skills that aligned with the preschool's curriculum and was integrated into the regular preschool day. The study suggests that, under certain conditions, the use of technology and interactive media can be a positive addition to the preschool learning environment.

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Appendix: Materials and Suggested Activities—Learning Station 2

Week 1: Cardinality

Topic: Identifying how many objects are in a group (cardinality).

Materials:

- Worksheet from PBS KIDS Lab: *Curious George's Busy Day* "High Five"
- *Chrysanthemum* (Greenwillow Books, 2011)
- Blank, large index cards or thick sheet of paper
- Unifix cubes
- Black marker

Some Suggested Activities:
Chrysanthemum Activity (Adapted from PBS KIDS Lab)

- Read book to interested children at learning station. On page 5, pause after reading the sentence, "Chrysanthemum thought her name was absolutely perfect." Ask children if they would like to count the letters in Chrysanthemum's name on the cover of the book.
- For children wishing to participate, write each student's name on the index card for him/her. Go around the table and count the letters in each child's name. Once they know how many letters are in their name, they will be given the same number of unifix cubes as there are letters in their name. Invite them to build a shape of their choice out of the cubes that they receive. If they say "I'm done!", invite them to build a brand new shape from the same blocks.

Extended Activity:
Curious George's Busy Day – High Five Activity (From PBS KIDS Lab)

- Complete the "High Five" worksheet from PBS KIDS Lab – counting how many fingers there are on the page.

Online Games Related to Lesson:
Count with Allie
Fair Shares
Ribbit

Week 1: Counting

Topic: Counting backwards from 10 to 0 and counting from 1 to 50.

Materials:

- *Bunches of Buttons* (Nonfiction Picture Books, 2006)
- Buttons (groups of 10) – different colors
- Egg carton
- Post-its
- *On the Launch Pad* (Nonfiction Picture Books, 2004)

Some Suggested Activities:

- Read *Bunches of Buttons* to interested children at the learning station, and show children how each page is counting by 10s all the way to 100.
- For children wishing to participate, give each student a group of 10 buttons, each a different color. Invite children to place each group of buttons in the egg carton, counting up by 10 as they go. Each egg carton space will be labeled 10, 20, 30, etc. using Post-its.
- Encourage children to count as high as they can.

Extended Activity:

- Read *On the Launch Pad* to blast the rocket into space.

Online Games Related to Lesson:

High Fives
Blast Off
Bunny Ride

Week 2: Identifying Digits

Topic: Identifying digits in numerical form, word form, and in a group.

Materials:

- Index cards with the digits 1–10
- Index cards with the words "one" through "ten"
- Pictures of animals/objects in sets of 1–10. For example: 1 lion, 2 penguins, 3 bears, etc.

Some Suggested Activities:

- For children wishing to participate, show children a set of pictures (1 lion, 2 penguins, etc.) and ask the children how many animals/objects are in the set.
- Once the children answer correctly, move the images to the side and place two digit cards, one correct and one incorrect, on the table. Ask the children which digit matches the number of images in the group.
- Once the children answer correctly, move the digit card so that it is sitting next to the group. Then, place two word cards, again one correct and one incorrect, on the table and ask the children to identify which word card matches the number of images.
- Complete this cycle for as long as children are interested or as time allows or until the cards run out.

Extended Activity:

- Encourage children to count by 10s from 0 to 120.

Online Games Related to Lesson:

Hide and Seek
Bubble Pop

Week 2: Comparing Numbers

Topic: Comparing numbers (e.g., identifying which group of dots is larger than the other).

Materials:

- Deck of large playing cards with face cards removed
- *Just Enough Carrots* (HarperCollins, 1997)

Some Suggested Activities:

- Read the book *Just Enough Carrots* to interested children at the learning station, and show the children how the book is comparing more, the same, and fewer. On each page where it uses this vocabulary, count how many items are in the "more," "same," and "fewer" boxes. Stop at the bottom of page 23.
- As an introduction to the activity, give each student wishing to participate one playing card between 1–10. Ask children to compare their card to the one the facilitator has in front of her, and to say if their card is bigger or smaller than the facilitator's.
- Give each student two playing cards between 1–10. Give children time to study their cards and then ask, "Which one is bigger?"
- Complete this cycle for as long as children are interested, as long as time allows, or until the cards run out.

Extended Activity:

- Encourage children to count from 0 to 50 by 2s and by 5s.

Online Games Related to Lesson:

Bug Catcher
Hat Grab
Monkey Jump

Week 3: "Number After"

Topic: Identifying which number follows in a set (i.e., 1, 2, 3, _, 5).

Materials:

- Math sequencing puzzles
- "Apple Picking" worksheet (from PBS KIDS Lab)

Some Suggested Activities:

- Invite interested children at the learning station to help figure out the missing numbers in the sequence as a group (working on one "Apple Picking" worksheet, which the facilitator is writing on). Help children by having them count out loud or work with their neighbor to figure out which number comes next.
    - Helpful hint: On the line that starts with 11, add an apple labeled "10" to help children with the sequencing.
- Complete one sequencing puzzle as a group. Point out to the children that the numbers always go on the bottom.
- Give each student wishing to participate a math sequencing puzzle (dinosaurs, bugs, etc.) with the pieces mixed up and ask them to put the numbers in order from 1 to 10. Once they have made the picture, mix up the pieces of each sequencing puzzle again and give each student a new puzzle to put together.

Extended Activity:

- Encourage children to practice counting backwards from 20.

Online Games Related to Lesson:

Apple Picking
Flower Garden
Meatball Launcher

Week 3: Simple Addition

Topic: Completing simple addition problems.

Materials:

- *Quack and Count* (HMH Books for Young Readers, 2003)
- Dough mats
- Beans (or other counter)
- Markers

Some Suggested Activities:

- Read *Quack and Count* to interested children at the learning station, making sure to show the children how addition is being used to make each number on the page.
- When the book reading is finished, give each student that wishes to participate two dough mats and a handful of beans. Invite children to make each of the numbers on the mat using the beans. Then, ask children to add the two numbers together and find the answer. The mats can be changed multiple times to give children the opportunity to make several addition sentences.
- Stop when time or combinations of mats run out.

Extended Activity:

- Encourage interested children to practice counting up from 20 to 100.

Online Games Related to Lesson:

Train Station
Museum of Tens