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Effect of the UMIGO Transmedia Property on First and Second Grade Students' Math Ability

Summative Evaluation B: Randomized Controlled Trial (RCT) Study – Year 4 & 5

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Background and Objectives

UMIGO Partnership

The UMIGO (yoU Make It GO) Partnership is led by Windows to the World Communications (WTTW Chicago) in collaboration with W!ldbrain Entertainment (DHX Media) and the Michael Cohen Group, LLC (MCG). This partnership is responsible for the development, production, and evaluation of UMIGO – an educational transmedia property designed to engender first- and second-grade children's early mathematics learning through online interactive adventures that engage young children in active learning through immersive storytelling.

In 2010, the UMIGO Partnership was awarded a five-year (2010-2015) Ready-to-Learn (RTL) grant from the U.S. Department of Education to promote early learning and school readiness through innovative transmedia programming, with an emphasis on reaching children from low-income families (United States Department of Education, 2010). UMIGO has been designed with the explicit goal of significantly raising young students' early math skills and academic achievement in line with the objectives of the RTL grant.

Overview

UMIGO endeavors to help young children attain basic math literacy and problem-solving through interactive transmedia, and in doing so, address an important educational need for our nation. Approximately half of American children are failing to meet proficient math standards (National Center for Education Statistics, 2011); a disproportionate number of these children are from low-income families. Foundational math skills are critical for academic achievement. Furthermore, the consequences of failing to acquire basic math competencies at an early age are far-reaching, including difficulties learning to read, disengagement from learning, and increased likelihood of dropping out of high school (Geary, 2011; Geary, Hoard, Nugent, & Bailey, 2012; Balfanz, 2007).

Learning through Transmedia

The UMIGO Partnership recognizes the importance of providing all children with a solid foundation in mathematics, especially for low-income American households. UMIGO provides a digital media-based mathematics curriculum for children aged 6-to-8 years (first and second grade) in the form of online interactive transmedia storytelling and math games, with corresponding support materials and online resources for parents, caregivers, and teachers.

Transmedia storytelling is defined as *conveying content and themes to audiences through the well-planned, connected use of multiple media platforms (examples include but may not be limited to: television, video, Web sites, cell phones, e-books, electronic games, handheld devices, and other yet to be developed technologies)* (United States Department of Education, 2010). Educational transmedia properties are comprised of a number of learning products from different media sources interconnected by a narrative and/or cast of characters. Each product exists independently and forms part of a cohesive transmedia property wherein learning becomes integrated across media platforms.

Popularity of media and technology with children. Children's media exposure and use of digital technology in the home has increased steadily since 2006 (Michael Cohen Group, 2009). Children aged 2-to-8 spend on average 21 hours a week engaged with media through multiple platforms, including music, books, television, computers, and video games (Common Sense Media, 2011; Michael Cohen Group, 2009). Children's media consumption increases with age; 8-to-18-year-olds now devote more than 53 hours a week to a multitude of media and technology (Rideout, Feehr, & Roberts, 2010).

Media and technology for educational purposes. Educational technology products are typically either designed to be tools used in a classroom (formal environment) with support from an educator (mediated learning) or to be tools used in the home (informal environment) without instruction (non-mediated learning). Products designed for informal, non-mediated learning,

such as educational television programs or learning apps, are necessarily designed to be effective without the presence of an instructor and therefore do not require extensive teacher training. These products typically embed the educational content within a game or narrative. Such educational products need to be highly entertaining and engaging because they must compete with other non-educational activities for children's time and attention.

Educational benefits of media properties for children. Research has examined the effects of educational television programming such as Sesame Street, Barney & Friends, and Word World in enhancing pre-literacy skills, numeracy, and social-emotional development among pre-school aged and older children. Specifically, as part of a 2005-2010 RTL grant, summative results concluded that children who viewed the Word World educational television program showed significant gains in pre-school vocabulary and early literacy skills (Michael Cohen Group, 2009; 2012)[1].

An important component of educational television is its ability to engage and motivate viewers through compelling narratives and songs (Fisch & Truglio, 2001; Hall, Williams, Cohen, & Rosen, 1993). As stated, this high level of engagement and appeal is critical to learning that occurs outside of formal educational settings, where educational media must compete with other activities for children's time and attention. However, television and video provide less opportunity for the practice of skills compared to interactive digital media.

Potential of digital media. UMIGO's focus on interactive digital media is intentional. Children's active engagement in digital media offers a promising pathway to capture the learner's attention in formal settings (e.g. classrooms) and informal settings (e.g. at home via personal computers, touchscreen tablets, or other digital devices) and engender non-mediated learning. In addition, the versatility and interactivity of digital media offers a unique opportunity

[1] The Word World summative study was submitted to the United States Department of Education as part of the 2005-2010 Ready to Learn initiative, and reviewed and approved by a representative of the Institute for Educational Sciences, as well as an expert panel convened by the Office of Innovation and Improvement.

to individualize the learning experience for the child (e.g. provide immediate feedback, practice skills, and adjust level of difficulty).

A growing body of literature indicates that young children learn effectively from entertaining, educational media–based games and tools (e.g., Castellar, Van Looy, Szmalec, & de Marez, 2013; Tamim et al., 2011). Interactivity inherent in digital media products can be a powerful means of teaching specific skills and stimulating cognitive development (Linebarger & Walker, 2005). These findings, along with evidence of children's increasing involvement with media, underscore the need to leverage the positive potential of digital media content and related technologies (Gee, 2003; Klopfer, Osterweil, & Salen, 2009).

Randomized Control Trials: Summative Evaluation A & B

With the omnipresence of digital technology in children's daily lives and the ever-growing body of research on the benefits of educational media, the UMIGO Partnership has created a transmedia property designed to improve foundational mathematics learning for first- and second-grade children through online interactive storytelling and games.

To assure the educational effectiveness of the property, the RTL grant includes summative research as an essential project component. The use of a Randomized Controlled Trial (RCT) design meets the Institute for Educational Statistics (IES) standards for establishing strong evidence of intervention efficacy. Two summative evaluations were conducted through RCT studies over the five-year grant period to assess the educational benefits of UMIGO. These two studies are referred to as "Summative Evaluation A" conducted in Year 3 of the grant and "Summative Evaluation B" conducted in Year 4 and 5. The current study reports on Summative Evaluation B.

Summative Evaluation A Overview. Summative Evaluation A was conducted in Year 3 of the grant and a formal report was submitted to the Department of Education in July 2013. Five hundred and fourteen first- and second-grade children were exposed to UMIGO in a classroom

setting at schools. The schools provided computers to access online components and mobile devices (iPad Minis) to access apps. Evaluators provided UMIGO paper workbooks. A range of UMIGO transmedia products (music videos, online games, iPad apps, board games, pencil-and-paper activities) across four curricular areas were tested (Early Arithmetic, Inequalities, Capacity, and Measurement). Significant effects of UMIGO were observed on children's acquisition of skills and knowledge in Capacity and Inequalities. Significant effects were not observed on children's acquisition of skills and knowledge in Early Arithmetic or Measurement (Michael Cohen Group, 2013).

Summative Evaluation B Overview. The current report presents the results of Summative Evaluation B conducted by MCG in Year 4 and 5 of the grant as part of the US Department of Education RTL Cooperative Agreement, assessing the educational benefits of the UMIGO transmedia property. This evaluation utilized an RCT study that included a home treatment condition where children interacted with the UMIGO property on computers and/or touchscreen tablets.

It is important to note that there are three key differences between the two summative studies: 1) In Summative Evaluation A, the treatment condition occurred in a school environment (i.e. formal environment). In Summative Evaluation B, the current summative study, the treatment condition occurred in the children's homes (i.e. informal environment); 2) Summative Evaluation B, the current summative study, assesses an updated version of UMIGO. The UMIGO property underwent creative changes during the transition from Year 3 to Year 4, resulting in the creation of Transmedia Suites. Each Transmedia Suite combines a set of related media into a cohesive transmedia bundle focused on a specific math lesson accessed online; 3) In Summative Evaluation A, the control condition consisted of a comparable commercial transmedia property (Math Blaster). In Summative Evaluation B, the control condition consisted of activity-as-usual.

UMIGO Property Overview

The UMIGO property consists of eight media bundles, referred to as 'Transmedia Suites,' accessed online via computer, touchscreen tablet, or smartphone. Each Transmedia Suite teaches a specific mathematics lesson through an 'appisode,' a multi-level game, and a music video. For the purposes of the current study, UMIGO was accessed online at umigoproject.com to allow for the recording of digital interaction and analysis (analytics). See Image 1 below for the Transmedia Suite layout on the UMIGO summative website.

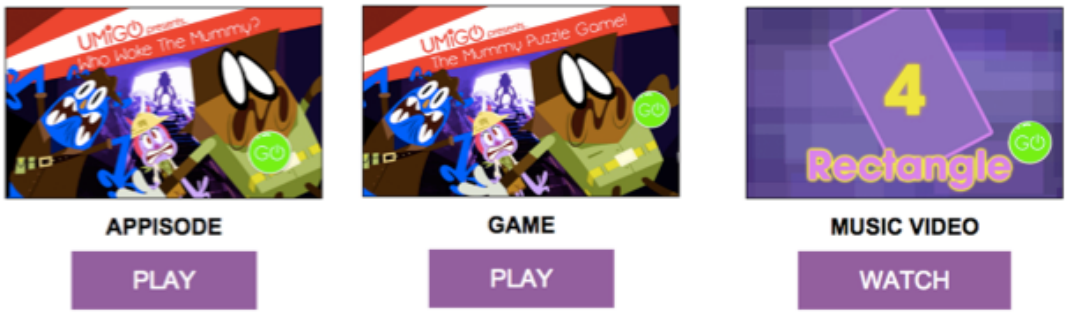


Image 1. Layout of the Transmedia Suites on umigoproject.com.

Appisodes. 'Appisodes' are online, narrative-driven videos with interactive features in which animated characters are confronted with mathematical challenges that illustrate and explain core math concepts. These appisodes are interspersed with 'Make-It-Go' moments (MIGs) embedded in the video where the child plays a short math game to help the characters solve the problem at hand.

Multi-level game. A stand-alone multi-level game in each Transmedia Suite builds upon the math concept in the appisode and provides the child with repeated practice of the core learning principles.

Music video. A music video in each Transmedia Suite features the UMIGO characters singing a catchy song with lyrics pertaining to the appisode's curricular theme and math concept.

Study Objectives

Educational television has been found to successfully teach curriculum content and model pro-social behavior (Fisch & Truglio, 2001; Michael Cohen Group, 2009; Singer & Singer, 2001). However, there is less research on the educational effects of interactive digital media, explicitly transmedia. The current evaluation is intended to assess the UMIGO transmedia property specifically. Additionally, the current evaluation contributes to the literature regarding educational transmedia.

The primary objective of this study is to assess whether children randomly assigned to use UMIGO at home (treatment condition) showed significantly greater increases in math knowledge and skills taught in UMIGO than children randomly assigned to activity-as-usual (control condition). The four UMIGO Transmedia Suites evaluated in this study focused on learning in four curriculum domains:

- Measurement of height and length;
- Addition to 10;
- Skip counting by 2s, 5s, and 10s; and
- Knowledge and construction of two-dimensional (2D) geometric shapes.

A secondary objective is to assess whether children randomly assigned to the UMIGO treatment condition showed significantly greater increases in affinity for mathematics than children assigned to the activity-as-usual control condition. UMIGO was not explicitly designed to impact children's attitudes towards mathematics. Nonetheless, the study is designed to assess the impact of UMIGO on children's level of affinity for mathematics in general.

There are three additional exploratory study objectives: 1) The study is designed to allow for an analysis of moderator effects of UMIGO. Moderator effects included participant demographics and educational characteristics. This design allows for the identification of specific subgroups of children that may potentially benefit from the UMIGO transmedia property; 2) The study is designed to explore and examine if learning gains are associated with the amount of time children engage with UMIGO Transmedia Suites. This allows for identification of the optimal interaction required to achieve UMIGO's educational objectives; 3) The study is designed to explore whether exposure to multiple UMIGO Transmedia Suites facilitated greater learning. Specifically, research assessed whether the educational effects of UMIGO are stronger if children interact with four Transmedia Suites as compared to two Transmedia Suites.

Each Transmedia Suite is designed to be self-contained and does not require mastery of specific prerequisite content. This self-contained structure is critical since UMIGO is designed for non-mediated learning and not as part of a sequenced, school-based curriculum. However, the UMIGO characters carry over from one Transmedia Suite to another, as do some of the mechanics of using the Transmedia Suites. Even though the curriculum of each Transmedia Suite is independent, it is possible that prior familiarity with UMIGO might make the products more engaging and easier to use, and thus might promote greater learning.

Method

Study Design

Summative Evaluation B tested the educational effects of the UMIGO transmedia property using a RCT design with a UMIGO at home treatment condition and an activity-as-usual control condition. The RCT study was conducted in two waves of testing, hitherto referred to as "Wave One" and "Wave Two". The two-wave design enabled testing of the new Transmedia Suites as the media bundles became available. Wave 1, completed in Fall 2014, tested Transmedia Suite 1 (Measurement) and Transmedia Suite 2 (Addition to 10). Wave 2,

completed in Spring 2015, tested Transmedia Suite 3 (Skip Counting) and Transmedia Suite 4 (2D Geometric Shapes).

In Wave One and Wave Two, children were randomly assigned to either a activity-as-usual control condition or the UMIGO at home treatment condition. Each wave consisted of 1) a pre-test of children's baseline math abilities and affinity; 2) an intervention period, where children either interacted with UMIGO Transmedia Suites (treatment condition) or engaged in their usual activities (control condition); and 3) a post-test of children's math abilities and affinity. Pre-test and post-test instruments were different for Wave One and Wave Two in order to assess the math curriculum specific to each Wave. The Math Affinity measure remained the same for both Wave instruments. Children who participated in both Waves were re-randomized between Waves, so that a child who had been in the UMIGO treatment condition in Wave One might be assigned to either the treatment condition or the activity-as-usual control condition in Wave Two.

Table 1. Transmedia Suites and math topics by study wave.

Study Wave	Math Topic	Transmedia Suite Number & Title
Wave One	Measurement	Transmedia Suite 1 *Nobody Rides the Soakster*
	Addition	Transmedia Suite 2 *Umiball*
Wave Two	Skip Counting	Transmedia Suite 3 *Scootie Doo*
	2D Geometric Shapes	Transmedia Suite 4 *Who Woke the Mummy?*

Criteria for strong evidence. The RCT study for Summative Evaluation B meets the criteria for strong evidence outlined by the U.S. Department of Education, including:

- Central random assignment of participants to Treatment and Control conditions;
- Intervention procedures that are standardized and documented to enable replication;

- The use of baseline data to confirm equivalence across conditions prior to the intervention and the statistical control of any differences not removed by randomization;
- The use of validated assessment measures when possible;
- Sample sizes that provide adequate power to detect treatment effects;
- The inclusion of multiple, geographically diverse sites to maximize external validity;
- Assertive follow-up procedures to limit attrition to less than 25%;
- In cases with substantial attrition, analyses which are conducted on an intent-to-treat basis, using multiple imputation methods to estimate outcomes for subjects lost to follow-up;
- The reporting of effect sizes and statistical significance;
- The reporting of positive and negative findings; and
- The examination of process, setting, and child factors that moderate or mediate treatment effects to further address external validity.

All procedures and materials were approved by an independent institutional review board (IRB) (See Appendix A).

Sample

The UMIGO target audience is first- and second-grade children, with a focus on children from low-income families. This study included children in the target grades, as well as kindergarten-aged children who were included out of concern for ceiling effects. It was hypothesized that there may be a ceiling effect due to the level of the math content, and therefore kindergarten children were included in the study.

Inclusion criteria. Children enrolled in the current study met the following qualifications listed below:

- Technology:
    - Internet Broadband access in the home;
    - Internet download speed of at least five megabits per second;
    - Operating system with Windows XP or higher on PC;
    - Operating system with 4.0 or higher on Android;
    - Windows Personal Computers (PC) or Android devices only in Wave One; Wave Two broadened to also include Macintosh devices (computers and iPads); and
    - Two Gigabytes of Random Access Memory (RAM) or higher.
- Grade: Kindergarten, first- and second- grade children;
- Sex: An equal mix of sexes;
- Geographic Location: Chicago, Illinois or New York, New York;
- Socioeconomic Status: Families with household income and making between $0 and $100,000 per year with an oversampling of low-income populations living at, near or below the poverty level;
- Race & Ethnicity: A representative mix of races/ethnicities.

Wave One Participant Profile. Of the 400 children enrolled in Wave One, 383 participants completed both pre- and post-test for a retention rate of 96%. Seventeen participants (4%) were excluded from analyses due to one or more of the following: failure to attend the post-test; asking to stop the interview; or emergent issues during the pre- or post-test phase (e.g., not understanding English, extreme disinterest).

Characteristics of Wave One participants are shown in Table 2. The randomization produced treatment and control groups that had similar characteristics at pre-test. Children in the two conditions did not differ significantly by grade, age, gender, study site (New York vs. Chicago), parent ethnicity, child ethnicity, parent education, or parental report of child's weekly digital media usage. Household income varied slightly by condition (chi-square (3 df) = 8.63, p <

.04) with more children assigned to the treatment condition from families with household incomes under $20,000 (16% for treatment versus 9% for control) and more children assigned to the control condition from families with household incomes between $20,000 and $40,000 (27% for treatment versus 39% for control). Pre-test scores on the Addition and Affinity outcome measures were similar for children in both conditions. However, pre-test scores on the Measurement scale were non-significantly lower (t (381 df) = 1.81, p < .07) among children in the treatment condition (mean = 3.17, SD = 1.62) than among children in the control condition (mean = 3.59, SD = 1.82). Therefore, pre-test scores were controlled in all analyses of post-test outcomes. Although children in both conditions did not differ significantly at pre-test, there was a non-significant difference on the Measurement scale. Therefore, scores were controlled for at pre-test.

Table 2: Characteristics of Wave One Participants by Condition

	Total	UMIGO	Control	χ^2 (df)	P
(n)	(383)	(196)	(187)		
Site				0.03 (1 df)	.86
New York	47%	47%	47%		
Chicago	53%	53%	53%		
Gender				2.45 (1 df)	.12
Female	52%	56%	48%		
Male	48%	44%	52%		
Grade				0.91 (2df)	.64
K	33%	35%	31%		

1	31%	29%	33%		
2	36%	36%	36%		
Age				1.06 (3 df)	.79
5	23%	25%	21%		
6	35%	33%	37%		
7	36%	36%	36%		
8	6%	6%	6%		
Household Income				8.63 (3 df)	.04
<$20k	13%	16%	9%		
$20-40k	33%	27%	39%		
$40-60k	29%	31%	28%		
$60-100k	26%	27%	24%		
Hours per week using media				2.38 (3 df)	.50
0-1	10%	10%	11%		
1-2	1%	0%	1%		
2-4	28%	29%	27%		
4 or more	61%	61%	62%		

	Total	UMIGO	Control	χ^2 (df)	P
(n)	(383)	(196)	(187)		
Parent education				5.78 (5 df)	.33
Some high school	2%	2%	3%		

High school graduate	13%	12%	13%		
Some college	41%	42%	40%		
College graduate	38%	37%	39%		
Some graduate school	2%	2%	3%		
Graduate degree	4%	6%	2%		
Parent ethnicity				2.32 (6 df)	.89
African-American	44%	45%	42%		
Asian/Pacific Islander	1%	1%	1%		
Caribbean	1%	1%	1%		
Caucasian	32%	33%	31%		
Hispanic	21%	19%	23%		
Hispanic & African-American	2%	2%	2%		
African-American & Caucasian	0%	0%	1%		
Child ethnicity				9.32 (10 df)	.50
African-American	43%	44%	42%		
Asian/Pacific Islander	1%	1%	1%		
Caribbean	0%	0%	1%		
Caucasian	28%	31%	25%		
Hispanic	20%	16%	24%		
Hispanic & African-American	3%	4%	3%		

African-American & Caucasian	1%	1%	2%
Hispanic & Caucasian	1%	1%	1%
Caribbean & Caucasian	0%	0%	1%
Asian & Caucasian	0%	1%	0%
Other	2%	2%	2%

Wave Two Participant Profile. Of the 335 participants enrolled in Wave Two, 310 participants completed both pre- and post-test for a retention rate of 92.5%. Twenty-five participants (7.5%) were excluded from analyses due to one or more of the following: failure to attend the post-test; asking to stop the interview; or emergent issues during the pre- or post-test phase (e.g., not understanding English, extreme disinterest).

Characteristics of Wave Two participants are shown in Table 3. Randomization produced treatment and control groups that did not differ significantly by grade, age, gender, study site (New York versus Chicago), household income, parent education, parent ethnicity, or child ethnicity. However, children in the control condition, according to parent report, significantly spent more time engaging with digital media (chi-square (3 df) = 6.14, $p < .05$): 72% of children assigned to the control condition as compared to 61% of children assigned to the UMIGO treatment condition typically spent four or more hours per week using digital media. There were no significant differences between children in the UMIGO treatment and control conditions in pre-test scores on any of the outcome measures (Skip Counting, 2D Geometric Shapes, and Math Affinity).

Table 3: Characteristics of Wave Two Participants

	Total	UMIGO	Control	χ^2 (df)	P
(n)	(**335**)[2]	(165)	(170)		
Site				0.00 (1 df)	.96
New York	50%	50%	49%		
Chicago	50%	50%	51%		
Gender				0.15 (1 df)	.70
Female	50%	52%	49%		
Male	50%	48%	51%		
Grade				1.67 (2df)	.44
K	31%	28%	34%		
1	35%	38%	32%		
2	34%	34%	34%		
Age				2.24 (4 df)	.69
5	16%	16%	16%		
6	36%	35%	37%		
7	36%	39%	33%		
8	11%	9%	13%		
9	1%	1%	1%		
Household Income				4.26 (3 df)	.24

[2] This number reflects all participants who completed the baseline measure.

<$20k	7%	7%	7%		
$20-40k	27%	22%	32%		
$40-60k	24%	27%	21%		
$60-100k	42%	44%	40%		
Hours per week using digital media				6.14 (3 df)	.05
0-1	5%	8%	3%		
1-2	--	--	--		
2-4	28%	31%	25%		
4 or more	67%	61%	72%		

	Total	UMIGO	Control	χ^2 (df)	P
Parent education				6.78 (5 df)	.24
Some high school	< 1%	< 1%	0%		
High school graduate	8%	7%	9%		
Some college	38%	44%	32%		
College graduate	42%	39%	45%		
Some graduate school	2%	1%	2%		
Graduate degree	10%	8%	11%		
Parent ethnicity				4.81 (7 df)	.68
African American	38.5%	39.4%	37.6%		
Asian/Pacific Islander/South Asian	3.6%	4.2%	2.9%		

Caribbean	0.3%	--	0.6%		
Caucasian	36.1%	35.2%	37.1%		
Hispanic	19.7%	20.0%	19.4%		
Hispanic & African American	0.9%	1.2%	0.6%		
Hispanic & Caucasian	0.3%	0.0%	0.6%		
Other	0.6%	0.0%	1.2%		
				9.42 (12 df)	.67
African American	37.6%	37.6%	37.6%		
Asian/South Asian/Pacific Islander	3.3%	3.6%	2.9%		
Caribbean	1.8%	2.4%	1.2%		
Caucasian	30.4%	29.1%	31.8%		
Hispanic	20.0%	20.0%	20.0%		
Hispanic & African American	1.2%	1.2%	1.2%		
African American & Caucasian	1.8%	2.4%	1.2%		
Hispanic & Caucasian	1.8%	1.2%	2.4%		
Caribbean & Caucasian	0.3%	0.0%	0.6%		
Asian & Caucasian	0.3%	0.6%	0.0%		
Hispanic & Asian	0.6%	1.2%	0.0%		
Caucasian & South Asian	0.3%	0.6%	0.0%		
Other	0.6%	0.0%	1.2%		

Characteristics of Dual-Wave Participants. Of the 335 participants in Wave Two, 172 (51.4%) had previously participated in Wave One. These participants were randomly assigned and evenly distributed across both Wave Two conditions (see Table 4).

Table 4. Profile of Wave One Participants in Wave Two

	Wave Two Sample		Wave Two UMIGO Treatment Participants		Wave Two Control Participants	
(n)	(335)		(170)		(165)	
New Participants	163	49%	80	47%	83	50%
Wave One UMIGO Treatment Participants	91	27%	44	26%	47	29%
Wave One Control Participants	81	24%	46	27%	35	21%

Wave One and Wave Two Instruments

Different instruments were created for Wave One (see Appendix E for researcher data coding form for Wave One instrument) and Wave Two (see Appendix G for researcher data coding form for Wave Two instrument). Each instrument had its own curricular measures. The same instruments were administered at pre- and post-test to compare math knowledge and ability before and after the treatment phase of the study.

The measure for Math Affinity was the same for both Waves (see Appendix C). The curricular measures for Wave One included Addition and Measurement (see Appendix D). The curricular measures for Wave Two included Skip Counting and Shapes (see Appendix F).

Math Affinity (Waves One and Two). The Math Affinity measures were derived from standardized Affinity instruments that assess children's self-perceptions of and attitudes towards math ability and enjoyment. To assess mathematics affinity in the current study, 10 questions were derived from two standardized affinity instruments that address children's self-perceived competency, anxiety, enjoyment, and comprehension of math. Questions were modified by simplifying and condensing the language to promote comprehension (see Appendix C for Math Affinity questions).

The first four questions in the Math Affinity measure were based on an instrument created to assess math anxiety in first-grade children attending Title I schools (Harari, Vukovik, & Bailey, 2013). These questions investigated children's enjoyment of mathematics. The remaining six questions in the Math Affinity measure were taken from an instrument assessing children's attitudes towards mathematics (Dowker & Thomas, 2000).

The scale has adequate internal reliability. Cronbach's alphas for the 10-item Affinity subscale were .70 at pre-test and .76 at post-test in the Wave One sample, and .77 at pre-test and .83 at post-test in the Wave Two sample.

Measurement (Wave One). A nine-item, task-based measure was used to assess participants' skills and knowledge of Measurement. This measure aligned with the UMIGO Transmedia Suite 1 *Nobody Rides the Soakster* curriculum that focuses specifically on Measurement. This measure was derived from an instrument on children's developing skills and knowledge of length and measurement (Szilagyi, Clements, & Sarama, 2013). Researchers posed nine questions verbally with physical materials that children interpreted or manipulated (see Appendix D for Measurement questions).

Cronbach's alpha for the nine-item Measurement subscale was .58 at pre-test and .60 at post-test, indicating less internal consistency than for the other scales.

Addition (Wave One). A 12-item measure was used to assess participants' skills and knowledge of Addition that involved addends to ten. This measure aligned with UMIGO Transmedia Suite 2 *Umiball* curriculum that focuses specifically on Addition to 10. Six of the questions were based on the Number Sense Brief Screen (NSB) (Jordan et al., 2010; Jordan, Glutting, et al., 2008). The other six questions were customized, following the same basic structure of the NSB questions, to highlight math problems with addends to ten (see Appendix D for all Addition questions).

The 12-item Addition scale had excellent internal reliability: Cronbach's alpha was .87 at both pre-test and post-test.

Skip Counting (Wave Two). A seven-item measure was used to assess participants' skills and knowledge of Skip Counting that involved two different types of skip counting. This measure aligned with UMIGO Transmedia Suite 3 *Umiball* curriculum that focuses specifically on Skip Counting. In the first four questions, children were asked to identify skip counting patterns performed by researchers with a frog puppet along a number grid (Briars & Siegler, 1984; LeFevre et al. 2006); in the remaining three questions, which were customized, children applied skip counting to count up grouped objects (see Appendix F for all Skip Counting questions).

The 10-item Skip-Counting scale demonstrated excellent internal reliability, with Cronbach's alpha of .81 at both pre-test and post-test.

2D Geometric Shapes (Wave Two). An eight-item measure was used to assess participants' skills and knowledge of 2D Geometric Shapes. This measure aligned with UMIGO Transmedia Suite 3 *Scootie Doo* curriculum that focuses specifically on 2D Geometric Shapes.

Four task-based questions were derived from measures that assessed children's abilities to construct and deconstruct geometric figures (Clements, Wilson, & Sarama, 2004). Four additional questions were custom-designed by MCG. Two of the customized questions pertained to shape recognition (specifically rectangles). The other two customized questions required assembly of 2D shapes out of other 2D shapes, the main concept highlighted in the UMIGO Transmedia Suite 3 (see Appendix F for all 2D Geometric Shape questions).

All questions were timed and scored on a performance scale (Clements, Wilson, & Sarama, 2004). Cronbach's alpha for the Shapes subscale was .71 at pre-test and .77 at post-test, also indicating adequate internal reliability.

UMIGO Treatment Stimuli

As previously stated, each UMIGO Transmedia Suite is comprised of three components: a full-length appisode, a multi-level game, and a music video. The transmedia components within a Transmedia Suite address the same math concept and reinforce each other. The eight Transmedia Suites are designed as non-sequenced and can be used in any order.

The Transmedia Suites for Wave One and Wave Two for the study were accessible online at www.umigoproject.com. Participants assigned to the UMIGO treatment condition were required to log into the website, which allowed for analytics tracking of usage.

Wave One - Transmedia Suite 1 and 2. Children assigned to the treatment condition of Wave One interacted with UMIGO Transmedia Suite 1 (Measurement) and Transmedia Suite 2 (Addition).

The appisode in Transmedia Suite 1 (Measurement), titled *Nobody Rides the Soakster*, tells a cautionary tale of failing to use standard units of measurement. The characters' objective is to standardize the height requirement for amusement park rides. The characters experiment with measurement using differently sized feet (see Images 2 & 3) before realizing that a standard unit of measurement (a ruler) is needed to achieve their goal (see Images 4 & 5).

Images 2 & 3. Measuring with differently sized feet results in different heights.

Images 4 & 5. Measuring with a standardized ruler has consistent results.

The appisode in Transmedia Suite 2 (Addition), titled *Umiball*, portrays a tense sports game that combines elements of rugby and basketball to practice Addition to 10. The players form different combinations of numbers by selecting groups of 'Umis' (little shapes that bounce around) and shooting them into baskets (see Images 6 & 7). The objective is to fill the scoreboard with all of the possible combinations of ten (see Image 8).

Images 6 & 7. Selecting groups of Umis to add to 10.

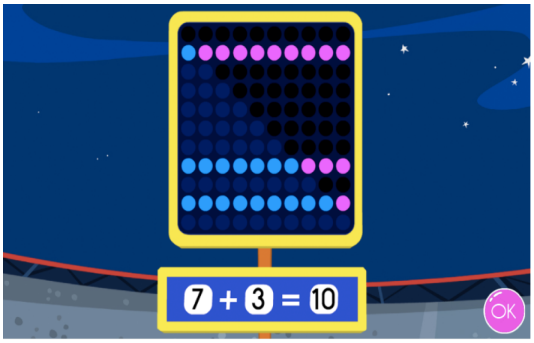


Image 8. Scoreboard, with the combinations of 1 + 9, 3 + 7, and 9 + 1 scored.

Wave Two - Transmedia Suite 3 and 4. Children assigned to the treatment condition of Wave Two interacted with UMIGO Transmedia Suite 3 (Skip Counting) and Transmedia Suite 4 (Shapes).

The appisode in Transmedia Suite 3 (Skip Counting), titled *Scootie Doo*, tells the story of a character's desire to earn a scooter by winning enough game tickets at an amusement park. The user helps the UMIGO characters by performing activities such as selecting the correct number of grouped objects or moving a character along a number board in a skip counting pattern (see Images 9, 10 & 11).

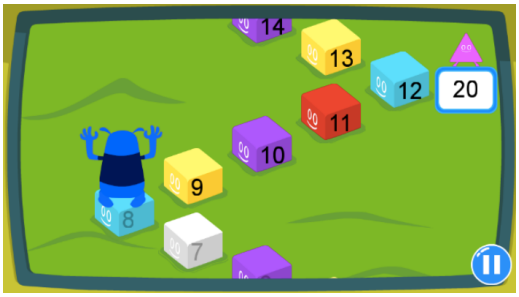
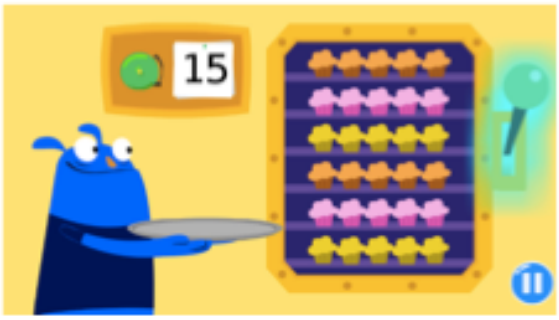


Image 9. Skip counting by 2s



Images 10 & 11. Skip counting by 5s on a number chart and skip counting by 5s with muffins.

The appisode in Transmedia Suite 4 (Shapes), titled *Who Woke the Mummy?*, follows the characters on an Indiana Jones-style quest to escape a mummy in hot pursuit. The user applies his/her knowledge about 2D shapes in various ways (selecting a certain shape, or forming a new shape out of constituent pieces) to help the characters flee (see Images 12 & 13).

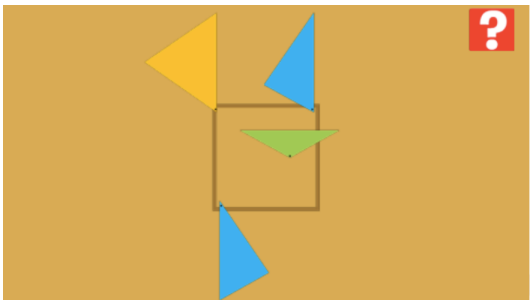


Image 12. Rotating triangles to make a square.

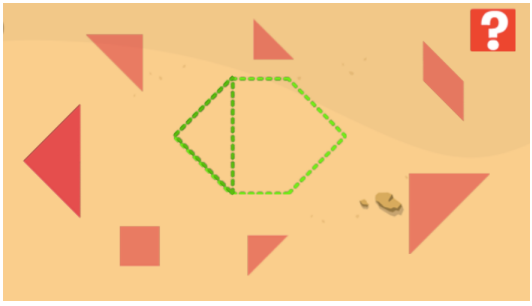


Image 13. Moving and rotating 2D shapes to make a pendant.

Procedure

Pre-test. A pre-test was administered prior to each wave. Researchers tested child participants one-on-one at a central site (MCG offices in New York; WTTW offices in Chicago). Researchers administered the assessment to children by posing questions verbally, presenting materials where relevant, and recording responses on a paper form (see Appendix E for Wave One researcher data coding form and Appendix G for Wave Two researcher data coding form). After each test was complete, the researcher transferred the recorded responses from the paper form to digital form (using an iPad to access a private online form). Each participant was assigned an identifying code number associated with their scores/data to ensure anonymity and protection of personal information. Parents of children assigned to the UMIGO treatment condition participated in a brief orientation to the UMIGO Transmedia Suites while their child was participating in the pre-test.

Treatment phase. Parents with children randomly assigned to the UMIGO treatment condition were provided with an instruction booklet, the link to the UMIGO website, a personal username and password to login to the website, and a logbook to record their children's use of the UMIGO Transmedia Suites (see Appendix B for example of parent instruction booklet).

In Wave One, parents of children assigned to the UMIGO treatment condition were asked to ensure their child interacted with UMIGO Transmedia Suites 1 and 2 for a minimum of 1.5 hours per Transmedia Suite (total 3 hours) over two weeks. Children's schedule of UMIGO play was completely flexible; children could play 3 hours in one session, or space their play out more evenly throughout the weeks. Parents and caregivers were instructed that the children were welcome to play more than the intervention dosage. Parents and caregivers of children randomly assigned to the control condition were simply asked to return with their children for the post-test in two weeks' time. To ensure fidelity of implementation, researchers sent a series of reminder e-mails to parents over the intervention period. Researchers also provided a Google Voice number that parents were encouraged to call with any questions or concerns.

Treatment conditions in Wave Two were similar to those in Wave One with two modifications: 1) Parents were instructed to have their child use UMIGO for a minimum of 5 hours; 2) The intervention period was shortened to 1 week from 2 weeks.

Post-test. Children returned to complete the post-test either two weeks (Wave One) or one week (Wave Two) after their pre-test date. The procedure was identical to that of the pre-test.

Data Analysis Plan

Measurement, Addition, Skip Counting, and 2D Geometric Shapes subscale scores were based on the total number of correct responses, with non-responses treated as incorrect responses. Math Affinity scores were calculated using a point scale from the total sum of all individual questions comprising the Math Affinity measure, computed only for children who responded to every question.

The effect of treatment condition on post-test scores was tested using linear regression, with pre-test score controlled as a covariate. Separate main effect models were run for each of the five outcomes (Measurement, Addition, Skip Counting, 2D Geometric Shapes, and Math Affinity). Additional moderator analyses tested whether the effect of intervention condition on outcomes varied across different subgroups of children. Predictors in these models included pre-test score, condition, the moderating variable, and a moderator x condition interaction term (moderation is present if this interaction term is statistically significant). There were nine potential moderators (study site, child age, child grade level, child gender, child score at pre-test, parent education, parent income, child ethnicity, and parental report of child's weekly digital media usage). Each potential moderator was assessed separately in a total of 45 moderator models (5 outcomes x 9 moderators = 45 models).

Additional item-level analyses tested whether gains on specific Addition or Measurement items varied by condition. Because item-level results are dichotomous (correct/incorrect),

logistic regression was used to control for pre-test response while assessing the effect of condition on item responses at post-test.

Results

Overview of Findings

Children showed improvement over time in all four of the educational outcomes (Measurement, Addition, Skip Counting, and 2D Geometric Shapes) across conditions in the RCT study of the Summative Evaluation B. Importantly, children assigned to the UMIGO treatment condition showed significantly greater improvement than children assigned in the control condition in one math outcome, skills and knowledge of 2D Geometric Shapes.

This results of Wave One and Wave Two are reported in this section as follows: 1) the usage of the Transmedia Suites by participants in the treatment condition (website analytics and parent log record); 2) learning outcomes and changes in Math Affinity among children in the treatment and control conditions; 3) within each outcome, overall differences in learning between the treatment and control conditions; 4) potential moderators of treatment effects, including associations between Transmedia Suite usage and learning outcomes.

Following the Wave One and Wave Two results, the effects of cumulative exposure to UMIGO are reported, regarding whether children randomized to the UMIGO treatment condition in both Waves One and Two showed greater gains in learning than children interacting with UMIGO for the first time in Wave Two.

Wave One – Transmedia Suite 1 and 2

Measurement & Addition

Usage

Transmedia Suite 1: Measurement. The content on Measurement was contained in Transmedia Suite 1, *Nobody Rides the Soakster.* Analytics usage data indicates that 194 out of 196 children (99%) in the UMIGO treatment condition engaged with Transmedia Suite 1. Median time of usage for Transmedia Suite 1 was 56.8 minutes (range = 0 to 251 minutes; see Table 3). Time spent using Transmedia Suite 1 was fairly evenly distributed between time viewing the appisode (median = 26 minutes) and time playing the multi-level game (median = 21 minutes; interquartile range = 9 to 40 minutes). Time viewing the music video was not captured due to technical difficulty. Analytics report that 22 participants (11.2%) of participants in the treatment condition met or exceeded prescribed intervention dosage (90 minutes). Parents reported higher estimates of their children's use of Transmedia Suite 1 (median = 98 minutes).

Transmedia Suite 2: Addition. The content on Addition to 10 was contained in Transmedia Suite 2, *Umiball.* Analytics usage data indicates 182 out of 196 children (93%) in the UMIGO treatment condition engaged with Transmedia Suite 2. Median time using Transmedia Suite 2 was 48 minutes (range = 0 to 312 minutes). Median time viewing the appisode of Transmedia Suite 2 was 19 minutes. Median time using the multi-level game was 21 minutes, but this varied widely: nearly one-third (32%) of children in the UMIGO treatment condition did not play the multi-level game at all, whereas the top 25% used it for 40 minutes or more. Time viewing the music video was not captured due to technical difficulty. Analytics report that 29 participants (14.8%) in the treatment condition met or exceeded intervention dosage (90 minutes).Parents reported higher estimates of their children's use of Transmedia Suite 2 (median = 105 minutes).

Technical issues impacting use. Children assigned to the UMIGO treatment condition encountered technical difficulties with both Transmedia Suites during Wave One. These difficulties included website freezing and long loading times. These technical issues also may have affected analytics and prevented some children from completing the appisode, multi-level game, or music video and may have discouraged future play.

Table 5: Use of Transmedia Suites 1 and 2

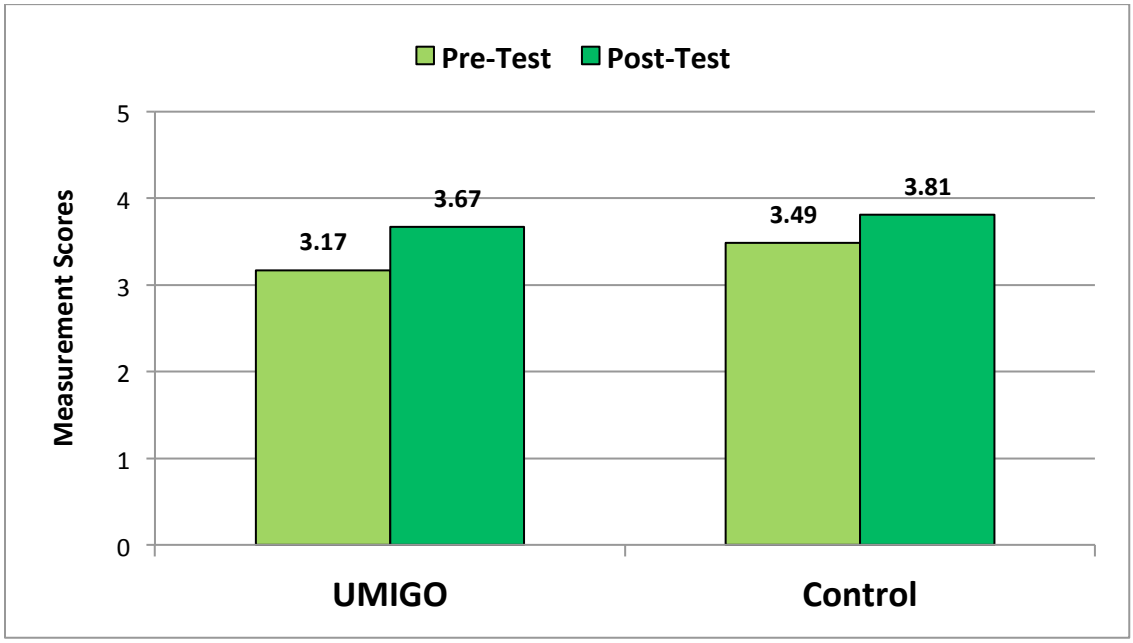
	Minimum	25th percentile	Median	75th percentile	Maximum
Transmedia Suite 1: *Nobody Rides the Soakster*					
Analytics data					
Total time (minutes)	0	35	57	73	251
Time viewing Appisode	0	16	26	52	107
Time playing Game	0	9	21	40	144
Parent report					
Number of sessions	0	3	4	5	13
Total time (minutes)	0	89	98	124	470
Transmedia Suite 2: *Umiball*					
Analytics data					
Total time (minutes)	0	21	48	76	312
Time viewing Appisode	0	9	19	34	90
Time playing Game	0	0	21	41	90
Parent report					
Number of sessions	0	3	4	5	14
Total time (minutes)	0	90	105	130	495

Measurement Outcomes

Measurement scores improved over time (pre-post d = 0.33, t (382 df) = 6.37, p < .001). Measurement scores improved similarly in both conditions, with no significant difference by the UMIGO treatment condition (beta = .029, t (1, 380 = 0.8, p < .40; see Figure 1 and Table 6).

Potential moderators. Moderator analyses confirmed that the effects of UMIGO on Measurement scores did not differ by study site, child age, child grade level, child gender, child addition scores at pre-test, parent education, parent income, child ethnicity, or the parental report of child's weekly digital media usage.

Figure 1: Wave One mean Measurement scores by condition and time



Note: Error bars indicate 95% confidence intervals

Table 6: Regression models of effect of treatment condition on post-test scores

	Measurement		Addition		Math Affinity	
(n)	(383)		(383)		(364)[a]	
	Beta	p <	Beta	p <	Beta	p <
Baseline score	.742	.001	.853	.001	.682	.001
UMIGO condition	.029	.40	.000	.999	-.013	.728
Model Fit	R^2 = .548, F (2,380) = 229.9, p < .001		R^2 = .727, F (2,380) =506.4, p < .001		R^2 = .466, F (2,361) = 157.5, p < .001	

[a] 19 cases excluded because of missing values.

Item-level responses. The proportion of children giving correct responses to each Measurement items are shown in Table 7. Children assigned to the treatment condition did not show significant improvement in any Measurement items than children assigned to the control condition.

Table 7: Proportion of Correct Responses to Each Measurement Item by Condition

	Pre-test		Post-test		Significance of post-test difference, controlling for pre-test scores [a]	
	UMIGO	Control	UMIGO	Control	Wald χ^2 (1 df)	p <
(n)	(196)	(187)	(196)	(187)		
Measurement average	35%	39%	41%	43%	--	--
M1	87%	84%	89%	88%	0.07	0.80
M2	47%	56%	52%	58%	0.04	0.84
M3	34%	41%	46%	52%	0.28	0.60
M4	69%	73%	79%	78%	1.39	0.24
M5	41%	41%	46%	50%	0.79	0.37
M6	13%	18%	20%	20%	0.95	0.33
M7	15%	18%	21%	21%	0.74	0.39
M8	3%	5%	3%	4%	0.03	0.87
M9	8%	13%	10%	12%	0.00	0.95

[a] Significance of the effect on condition in logistic regression predicting post-test response from pre-test response and condition.

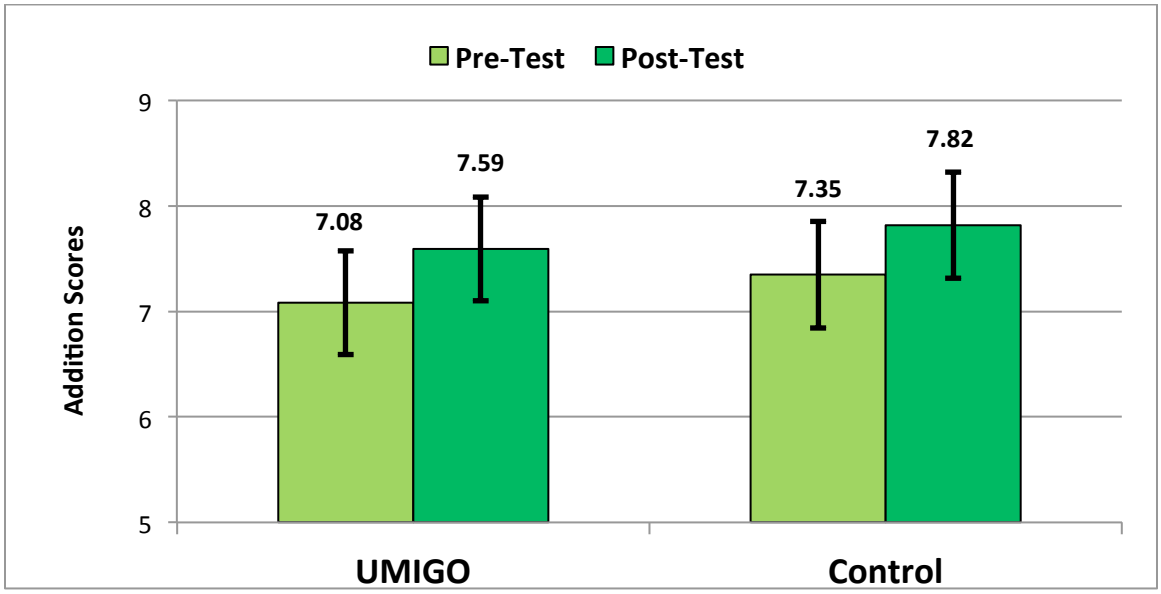
Association between Transmedia Suite 1 use and Measurement scores. Measurement outcomes were not correlated with the usage of Transmedia Suite 1, *Nobody Rides the Soakster* overall (r = -.031, ns). Additionally, outcomes were not correlated with the usage of the

Transmedia Suite components, including time viewing appisode 1 (r = .009, ns), or time playing the multi-level game 1 (r = .015, ns).

Addition Outcomes

Addition scores improved over time (pre-post d = .26, pre-post t (382 df) = 5.14, p < .001). Addition scores improved similarly among children in both conditions (see Figure 2). Controlling for pre-test scores, there was no main effect of UMIGO treatment condition on Addition scores at post-test (beta = .00, t (1, 380) = 0.0, p < .99; see Table 6).

Figure 2: Wave One mean Addition scores by condition and time



Note: Error bars indicate 95% confidence interval.

Potential moderators. Moderator analyses showed that the effects of treatment condition on Addition scores did not differ by study site, child age, child grade level, child gender, child addition scores at pre-test, parent education, parent income, child ethnicity, or parental report of child's weekly digital media usage.

Item-level analysis. The proportion of children giving correct responses to each Addition item is shown in Table 8. Children assigned to the treatment condition did not show significant improvement in any Addition items than children assigned to the control condition.

Table 8: Proportion of Correct Responses to Each Addition Item by Condition

	Pre-test		Post-test		Significance of post-test difference, controlling for pre-test scores [a]	
	UMIGO	Control	UMIGO	Control	Wald χ^2 (1 df)	p <
(n)	(196)	(187)	(196)	(187)		
Addition Average	59%	61%	63%	65%	--	--
ADD1	71%	74%	74%	81%	2.38	0.12
ADD2	37%	34%	40%	41%	0.29	0.59
ADD3	54%	63%	62%	64%	0.09	0.76
ADD4	34%	34%	40%	36%	0.57	0.45
ADD5	71%	74%	72%	74%	0.08	0.78
ADD6	62%	61%	68%	70%	0.63	0.43
ADD7	40%	42%	46%	49%	0.10	0.75
ADD8	34%	30%	38%	37%	0.06	0.81
ADD9	85%	84%	88%	90%	0.49	0.48
ADD10	70%	72%	71%	77%	1.65	0.20
ADD11	81%	87%	86%	90%	0.03	0.87
ADD12	69%	79%	73%	74%	0.03	0.87

[a] Significance of the effect on condition in logistic regression predicting post-test response from pre-test response and condition.

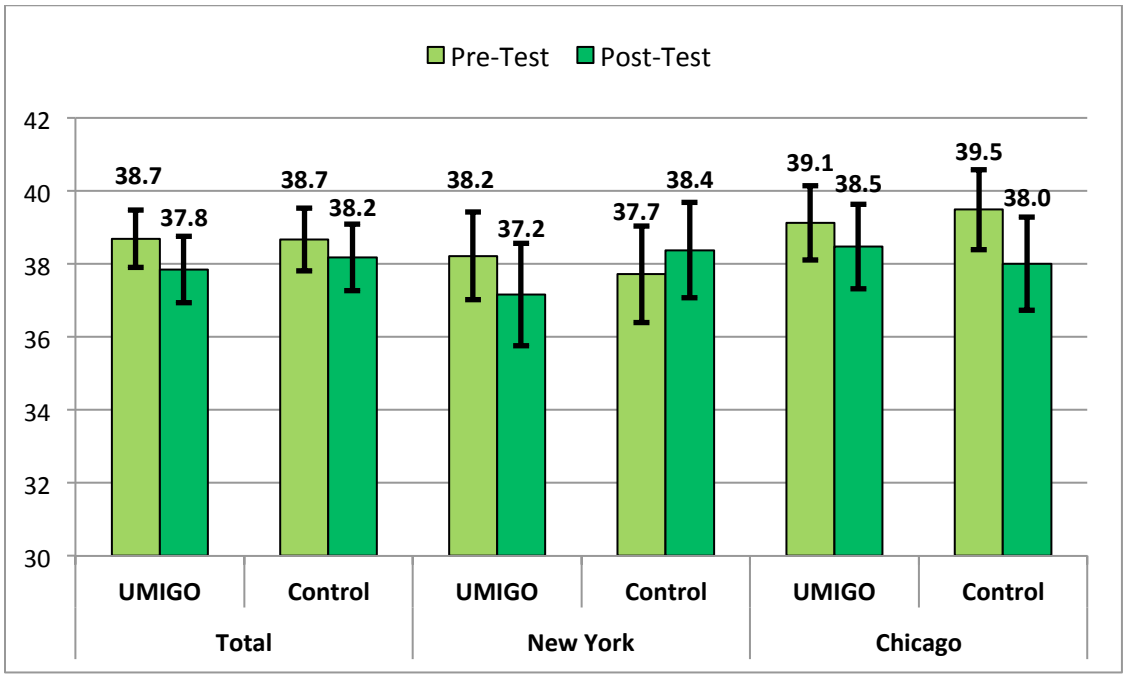
Association between Suite usage and Addition scores. Addition outcomes were not correlated with the usage of Transmedia Suite 2, *Umiball* overall (r = -.031, ns). Additionally, outcomes were not correlated with the usage of the Transmedia Suite components, including time viewing appisode (r = -.046, ns), or time playing leveled game 2 (r = -.021, ns).

Math Affinity Outcomes

Math Affinity scores decreased over time in Wave One across conditions (pre-post d = -.11, pre-post t (364 df) = 2.59, p < .02). Controlling for pre-test scores, there was no main effect of the UMIGO treatment condition on Math Affinity scores at post-test (t (1, 380) = -0.4, p < 0.73; see Figure 3 and Table 6).

Moderator analyses. There was a significant interaction of condition with study site (F (1,359) = 5.80, p < .02) in predicting Math Affinity scores. As shown in Figure 3, Math Affinity scores decreased more among children assigned to the control condition than children assigned to the UMIGO treatment condition in Chicago, whereas the reverse was true in New York. Follow-up regression analyses showed no significant effect on treatment condition on post-test Math Affinity scores by sites, Chicago (t (1,188) = 1.45, p < .15) and New York (t (1, 170) = -1.92, p < .06). Math Affinity scores did not vary by child age, child grade level, child gender, child addition scores at pre-test, parent education, parent income, child ethnicity, or the parental report of child's weekly digital media usage.

Figure 3: Wave One Math Affinity scores by condition, time, and site



Note: Error bars indicate 95% confidence interval.

Association between Suite usage and Math Affinity scores. Math Affinity outcomes were not associated with Transmedia Suite 1 (Measurement) or Transmedia Suite 2 (Addition) usage. Pre-post change scores for Math Affinity were not significantly associated (all r's $\leq$ .10, ns) with usage data from analytics for Transmedia Suite 1 or 2, or with parent's reports of the participant's Transmedia Suites 1 or 2 usage.

Wave Two – Transmedia Suite 3 and 4

Skip Counting & 2D Geometric Shapes

Usage

Transmedia Suite 3: Skip Counting. Educational content on Skip Counting was contained in Transmedia Suite 3, *Scootie Doo*. Analytics usage data indicates that all 165 children assigned to the UMIGO treatment condition used Transmedia Suite 3. Median time using Transmedia Suite 3 was 69.5 minutes (range = 0 to 204 minutes; see Table 9). Children spent most of the time viewing the appisode (median = 33.0 minutes) or playing the multi-level game (median = 22.8 minutes), with much less time (median = 6.6 minutes) spent viewing the music video. Analytics report that 49 participants (29.7%) met or exceeded intervention dosage (90 minutes). Parents reported higher estimates of their children's use of Transmedia Suite 3 (median = 161 minutes).

Transmedia Suite 4: 2D Geometric Shapes. Educational content on 2D Geometric Shapes was included in Transmedia Suite 4*, Who Woke the Mummy?*. Usage data indicates that 161 out of 165 children (98%) assigned to the UMIGO treatment condition engaged with Transmedia Suite 4. Median time using Suite 4 was 76.7 minutes (range = 0 to 226 minutes; see Table 9). Children spent most of the time viewing the appisode (median = 34.7 minutes) or playing the game (median = 27.8 minutes), and fairly little time (median = 4.6 minutes) viewing the music video. Analytics report that 55 participants (33.3%) met or exceeded intervention dosage (90 minutes). Parents reported higher estimates of the children's use of Transmedia Suite 4 (median = 162 minutes).

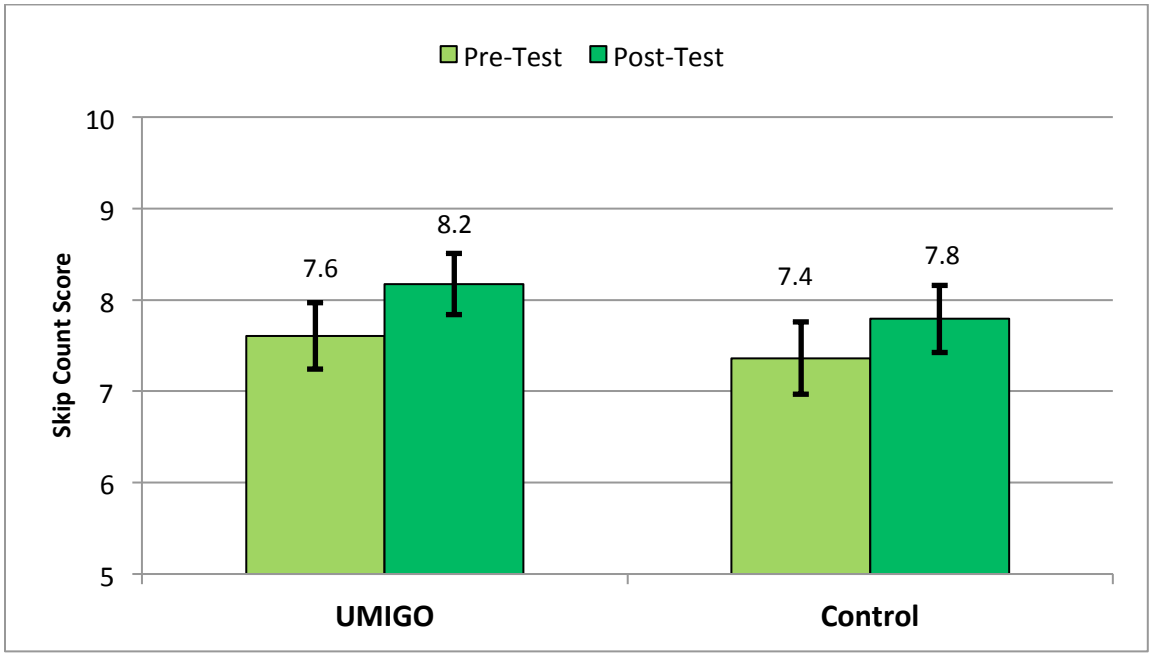
Table 9: Use of Transmedia Suites 3 and 4

	Minimum	25th percentile	Median	75th percentile	Maximum
Transmedia Suite 3: *Scootie Doo*					
Analytics data					
Total time (minutes)	0	37	70	98	205
Time viewing Appisode	0	15	33	51	172
Time playing Game	0	3	23	36	133
Time watching Music Video	0	0	7	13	89
Parent report					
Number of sessions	0	3	5	6	25
Total time (minutes)	0	125	161	193	399
Transmedia Suite 4: *Who Woke the Mummy?*					
Analytics data					
Total time (minutes)	0	29	77	103	227
Time viewing Appisode	0	9	35	52	156
Time playing Game	0	2	28	45	115
Time watching Music Video	0	0	5	10	74
Parent report					
Number of sessions	0	3	4	5	30
Total time (minutes)	0	121	162	185	375

Skip Counting Outcomes

Skip Counting scores improved over time (pre-post d = .22, pre-post t (309 df) = 3.78, p < .001). Skip Counting scores improved similarly in both conditions, with no significant difference by the UMIGO treatment condition (beta = .043, t (1, 307 df) = 1.36, p < .18; see Figure 4 and Table 10).

Figure 4: Wave Two mean Skip Counting scores by condition and time



Note: Error bars indicate 95% confidence interval.

Table 10: Regression models of the effect of treatment condition on Wave Two post-test scores

	Skip Counting		Shapes		Math Affinity	
(n)	(310)		(310)		(310)	
	beta	p <	Beta	p <	beta	p <
Baseline score	.831	.001	.685	.001	.785	.001
UMIGO condition	.043	.176	.170	.001	.049	.001
Model Fit	R^2 = .696, F (2,307) = 351.3, p < .001		R^2 = .509, F (2,307) = 159.4, p < .001		R^2 = .613, F (2,307) = 242.9, p < .001	

Potential moderators. Moderator analyses confirmed that the effects of treatment condition on Skip Counting scores did not differ by study site, child age, child grade level, child

gender, child addition scores at pre-test, parent education, parent income, child ethnicity, or parental report of child's weekly digital media usage.

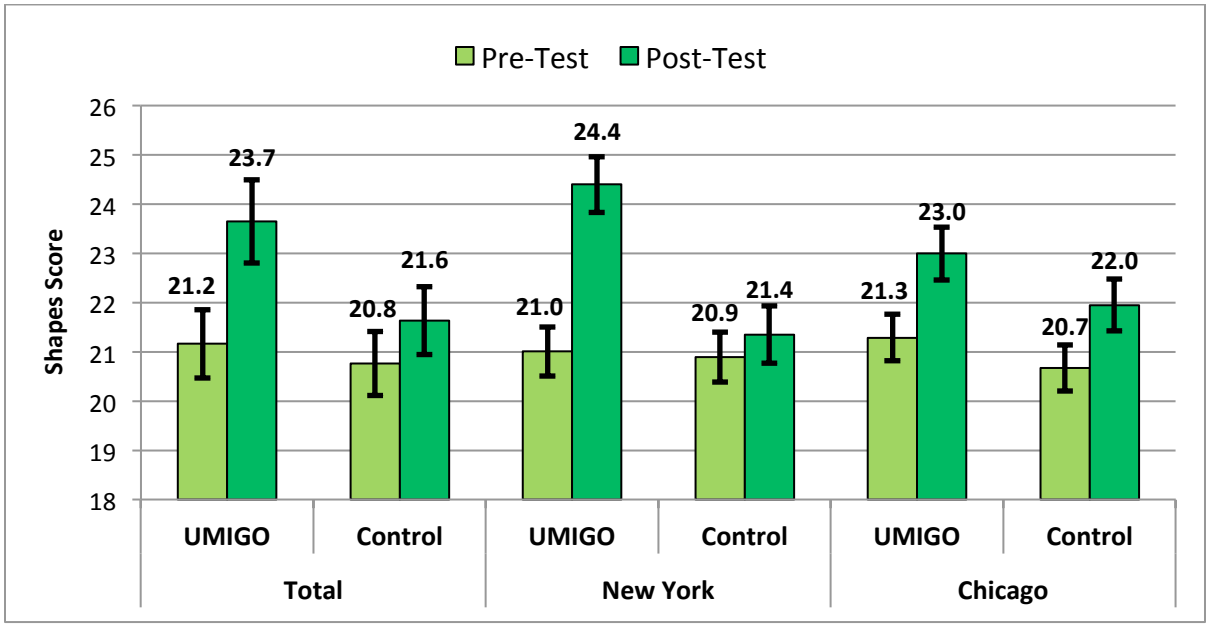
Association between Transmedia Suite usage and Skip Counting scores. Skip Counting outcomes were not correlated with the usage of Transmedia Suite 3, *Nobody Rides the Soakster* overall (r = .075, ns). Additionally, outcomes were not correlated with the usage of the Transmedia Suite 3 components, including time viewing appisode (r = .022, ns), time playing leveled game 2 (r = .074, ns), or time viewing the music video (r = .097, ns).

2D Geometric Shapes

2D Geometric Shapes scores improved over time across the treatment and control conditions (pre-post d = 0.47, t (309 df) = 8.32, p < .001). Children assigned to the UMIGO treatment condition showed an average of 1.7 points greater improvement in 2D Geometric Shape scores over time than children assigned to the control condition, a difference that was statistically significant (d = 0.35, beta = .170, t (307 df) = 4.24, p < .001; see Table 10 and Figure 5).

Potential moderators. The effect of UMIGO on Shape scores varied significantly by study site (condition x site interaction t = 3.16, p < .002). The effect of UMIGO on learning of shapes was significantly higher for children in New York than among children in Chicago (see Figure 5). Additional moderator analyses found that the effects of UMIGO on the learning of Shapes did not differ by child age, child grade level, child gender, child addition scores at pre-test, parent education, parent income, child ethnicity, or the parental report of child's weekly digital media usage.

Figure 5: Wave Two mean Shapes scores by condition, site, and time



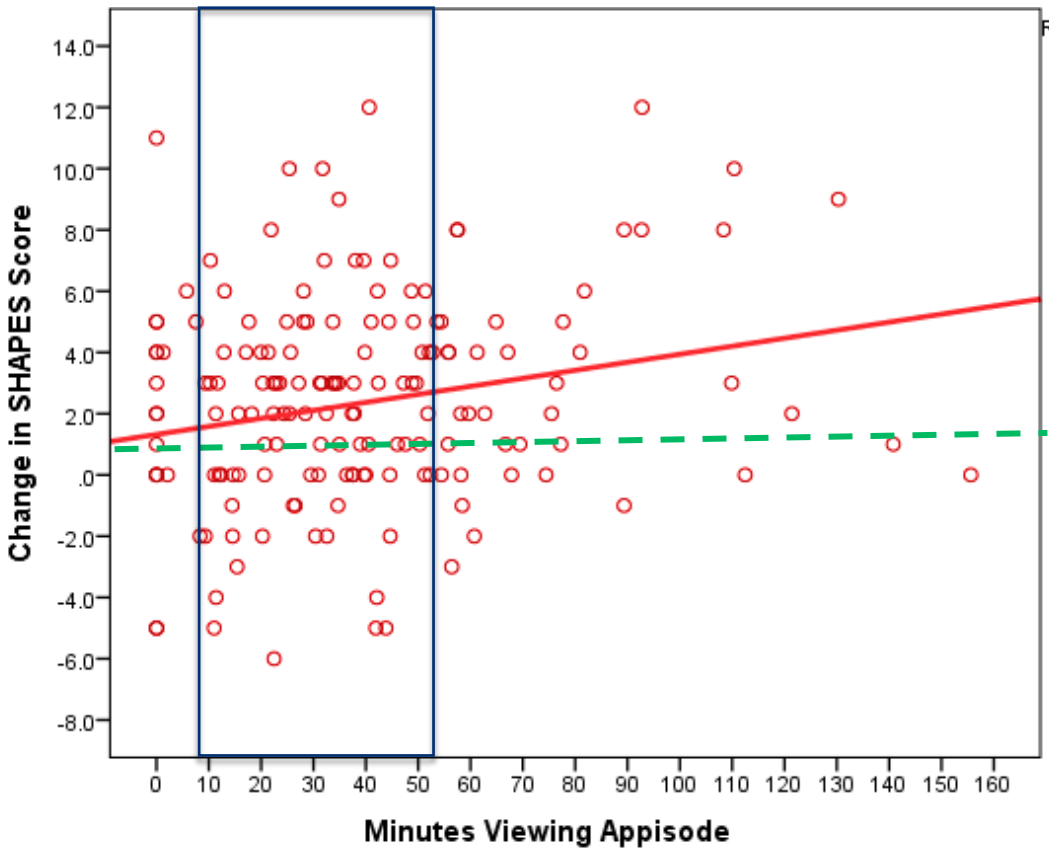
Note: Error bars indicate 95% confidence interval.

Association between Transmedia Suite usage and Shape scores. There was a positive correlation between Shape learning scores and Transmedia Suite 4 usage. The pre-post improvement was significantly correlated ($r = .205$, $p < .01$) with the usage data on how long the child viewed the appisode. The pre-post improvement was not significantly correlated with usage data on the multi-level game 4 ($r = -.051$, ns) or viewing the music video 4 ($r = -.04$, ns), or total time using all components of Transmedia Suite 4 ($r = .105$, ns).

The association between the time viewing the appisode of Transmedia Suite 4 and gains in Shape scores is shown graphically in Figure 6. The red regression line indicates how appisode usage was associated with gains in Shape scores among children assigned to the UMIGO treatment condition. The dotted green reference line indicates the mean improvement in Shapes scores among children assigned to the control condition. Children assigned to the treatment condition who spent less than 8 minutes viewing the appisode had gains in Shape knowledge that are similar to the children assigned to the control condition, whereas children

assigned to the treatment condition who spent more than 8 minutes viewing the appisode showed substantially greater improvement than children assigned to the control condition.

Figure 6: Scatterplot of Change in Shapes Scores by Time Viewing Appisode 4



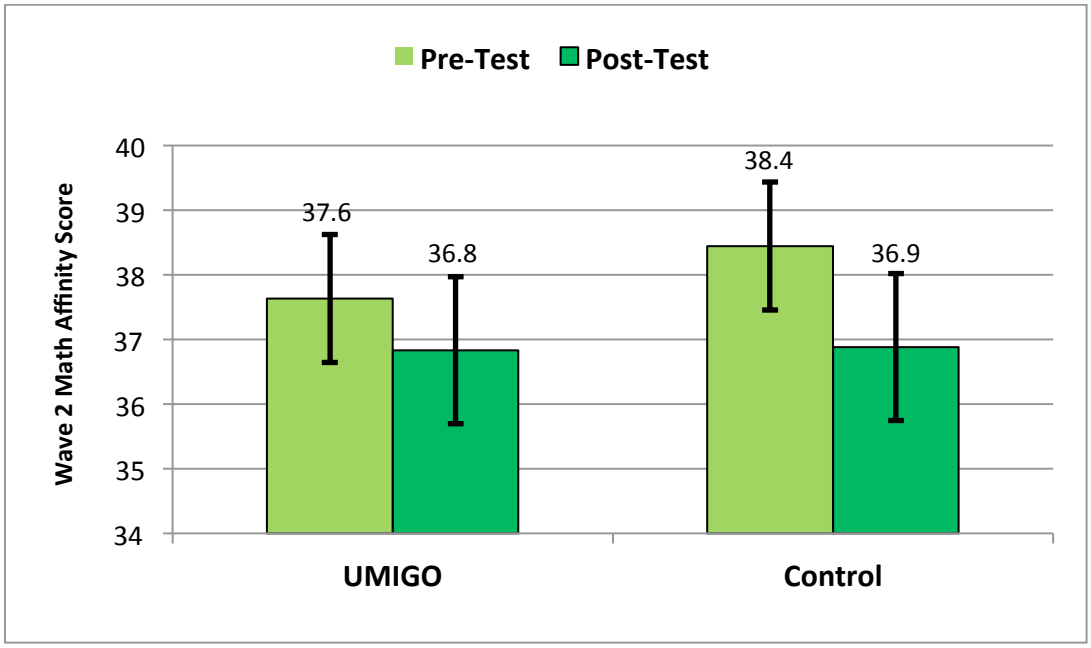
Note: The red line indicates the mean change in Shapes scores among children assigned to the UMIGO treatment condition by time viewing the appisode of Transmedia Suite 4. The blue rectangle indicates children assigned to the treatment condition in the 25th to 75th percentile of time spent viewing the appisode. The dotted green line indicates the mean change in Shapes scores among all children assigned to the control condition.

Affinity for Mathematics

Math Affinity decreased over time in the Wave Two sample across conditions (pre-post d = .26, pre-post t (308 df) = 4.59, p < .001; see Figure 7). As shown in Table 10, the decline in Math Affinity scores did not differ between children assigned to the UMIGO treatment condition and control conditions (beta = .049, t (1, 307) = 1.37, p < .17).

As in Wave One, Affinity scores declined over time whereas scores on other learning outcomes increased. Changes in Math Affinity scores from pre-test to post-test were not correlated with changes in scores for either Skip Counting (r = .001, p < .99) or Shapes (r = -.019, p < .73).

Figure 7: Wave Two Math Affinity scores by condition and time



Note: Error bars indicate 95% confidence interval.

Moderators. In Wave Two, the (lack of) effect of the treatment condition on Math Affinity scores did not vary by child age, child grade level, child gender, child addition scores at pre-test, parent education, parent income, child ethnicity, or the parental report of child's weekly digital media usage.

Association between Transmedia Suite usage and Math Affinity scores. Math Affinity scores were not associated with how much time children spent engaging with the either Transmedia Suite 3 or Transmedia Suite 4. Pre-post changes in Math Affinity scores were not significantly correlated with automated records of total time engaging with Suite 3 (r = .013, ns), time viewing appisode 3 (r= .014, ns), time playing the multi-level game in Suite 3 (r = -.009, ns), time viewing the music video in Suite 3 (r = .042, ns), total time engaging with Suite 4 (r = .026, ns), time viewing appisode 4 (r= .065, ns), time playing the leveled-game in Suite 4 (r = -.044, ns), or time viewing the music video in Suite 4 (r = ..046, ns).

Cumulative Effects of UMIGO in Waves One and Two

The concepts presented in Wave Two did not specifically build on the concepts introduced in Wave One. Nonetheless, there was potential for a cumulative effect on learning if the experience of using UMIGO in Wave One might make a child more comfortable and engaged when using UMIGO in Wave Two.

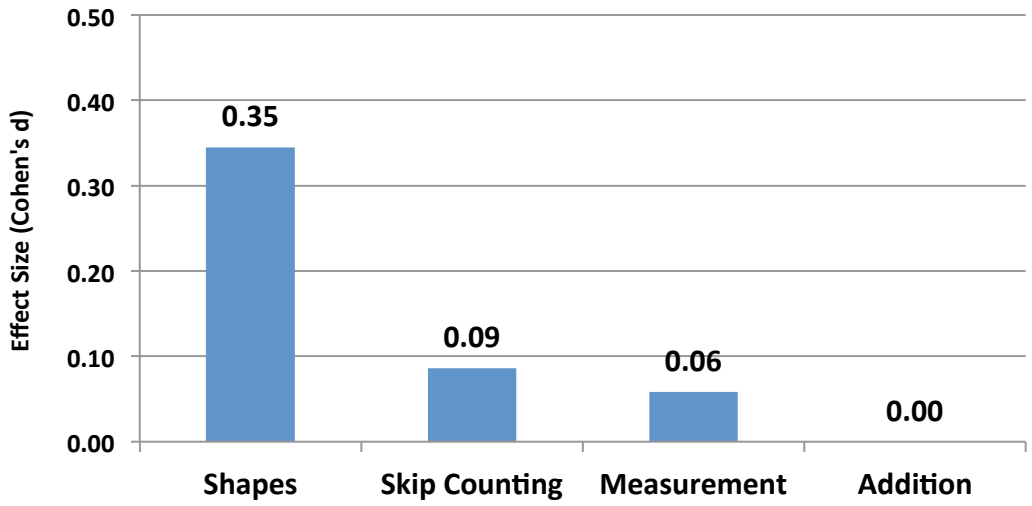
Cumulative effect was assessed by testing whether Wave One status (either UMIGO treatment, control, or not in Wave One) moderated the effect of Wave Two condition (UMIGO treatment or control) on Wave Two outcomes. There were no significant interactions of Wave One condition x Wave Two condition in predicting post-test scores on Skip Counting ($F(2, 303\ df) = 0.4$. $p < .79$), Shapes ($F(2, 303\ df) = 1.7$, $p < .18$), and Math Affinity ($F(2, 303\ df) = 1.2$, $p < .30$).

Comparison of the Four Learning Outcomes in Waves One and Two

Figure 8 summarizes the differences between children assigned to the UMIGO treatment condition and control conditions on the four key learning outcomes in Waves One and Two. To facilitate comparison across different outcome measures, the differences between the UMIGO treatment and control conditions are all expressed in standardized effect size units, Cohen's d.

There was a statistically significant effect on UMIGO treatment on one outcome, knowledge of 2D Geometric Shapes, which was taught in Transmedia Suite 4. The effect size was d = .35, a small-to-medium sized effect. The observed effects of UMIGO on the other three learning outcomes were all very small (d < .10) and not statistically significant.

Figure 8: Effect of UMIGO vs. Control; on Wave One and Wave Two Learning Outcomes



Note: Bars indicate difference in post-test scores between UMIGO and control children after controlling for pre-test scores. Outcomes are expressed in standard deviation units (Cohen's d).

DISCUSSION

The current study provides strong evidence that UMIGO is an effective educational math intervention. Results also add to the growing literature on effective, well-designed transmedia. The overall goal of 2010-2015 RTL grant was focused on the optimal use of media to engender young children's acquisition of foundational math skills and knowledge. UMIGO is specifically designed to aid in first- and second-grade students' acquisition of grade-appropriate math and numeracy skills and knowledge. Results indicate two important findings: 1) Children in both treatment and control conditions showed gains over time in their skills and knowledge across all curriculum areas, including; Measurement, Addition, Skip Counting, and Shapes; 2) Children assigned to the UMIGO treatment condition showed significant gains in one of the four educational outcomes, knowledge of 2D Geometric Shapes. (The small-to-medium effect size is similar to outcomes reported in the earlier UMIGO Summative Study A, comparing UMIGO transmedia materials to a comparator product).

These results are striking and raise several critical questions. UMIGO significantly aids in first- and second-grade students' learning in an important area of math curriculum – 2D Geometric shapes. However, children's interaction with UMIGO did not result in significant differences in learning for other curriculum areas addressed. The key question raised is why and how did UMIGO significantly aid in one curriculum area and not all. Results indicate that the expected potential ceiling effect did not occur – and a different confounding and unexpected result was reported. Learning occurred for children in both conditions in all curriculum areas.

There are several approaches to understanding these findings, including; methodological and technical vicissitudes; curricular factors of non-mediated, educational intervention for children attending school, and pedagogical features within UMIGO.

Methodological factors which may have limited effects of the UMIGO treatment condition. The core characteristics of the transmedia delivery model pose methodological

challenges for evaluation, especially in regards to home interventions. The RCT design of Summative Evaluation B was designed to be consistent with standardized requirements of an experimental randomized control trial. However, the transmedia experience is an intervention characterized by the absence of a standardized exposure and experience across students, as children actively choose and develop their own experiences with UMIGO.

Digital analytics provide a valuable record of the participant's interactions with UMIGO at home in the treatment condition, both in terms of overall usage as recorded by the website and the ways the participant interacted with different media within the Transmedia Suites. Parents of children in the treatment condition reported higher usage of the UMIGO Transmedia Suites than recorded by analytics usage data. This variation in usage data (analytics vs parent log records) raises questions about the function of parents as proxy for implementation of intervention dosage at home (i.e. without guided instruction by researcher or teacher) and the reliabilty of analytics data when technical issues are taken into consideration.

Technological issues which may have limited effects of the UMIGO treatment condition. Technical issues, such as website freezing and extensive loading times, may have affected analytics and children's overall engagement with the learning content of Transmedia Suite 1 and 2 in Wave One, as reported in the Wave One results. The majority of these technical issues were resolved by the time testing began for Wave Two.

Curriculum may contribute to and explain the stronger effects for 2D Geometric Shapes than for other educational outcomes. Summative Evaluation B began early in the school year before children had been exposed to most of the year's math curriculum. The non-significant comparative effects for UMIGO on Measurement, Addition, and Skip Counting does not seem to be explained by ceiling effects (i.e., children having such high scores at pre-test that there was no room to improve). Children's average pre-test scores on Addition (addends to ten), Measurement, and Skip-Counting were all below 70% of the maximum, indicating substantial room for further improvement. All three of these outcomes improved over time (pre-post d = .22

to .30) for all children in both the treatment and control conditions; however, there was no significant incremental value from exposure to learning content in UMIGO Transmedia Suite 1, 2, and 3 among children assigned to the treatment condition. It is possible that the learning content in Transmedia Suite 1, 2, and 3 was similar to, and supportive of, existing first- and second-grade classroom math instruction in Measurement, Addition, and Skip Counting for children in the treatment condition.

Pedagogical reasons why there were stronger effects for 2D Geometric Shapes than for other educational outcomes. The current study does not provide an explanation for how and why the UMIGO materials significantly improved children's learning of Shapes. However, the Transmedia Suite 4 appisode provides more constructivist learning opportunities and offers a digital version of physical math manipulative tools used in classrooms. Of the four suites, Transmedia Suite 4 has the strongest narrative and most experiential interactive games, wherein the user manipulates shapes to solve puzzles within a narrative. This opportunity to "learn by doing" may have aided learning. It is important to note that Transmedia Suite 4 was the most recently completed product tested and may indicate that the instructional design of UMIGO materials was improving over time.

Transmedia Suite 1 (Measurement) provides some opportunity for manipulating objects in its interactive activities and games, but the math problems are more abstract and may be less developmentally appropriate as media-based curriculum for students. Transmedia Suite 2 (Addition) is less experiential, with interactive tasks more akin to conventional homework exercises, and thus offers less incremental value. Transmedia Suite 3 (Skip Counting) may be limited by including too many different methods of skip counting and may be confusing to children. Transmedia Suite 3 alternates between numerical and visual exercises in skip counting; for example, in one exercise the user engages in skip count by recognizing numbers (i.e. 2, 4, 6, 8), and in other exercises the user skip counts by recognizing and skip counting groups of objects (i.e. skip counting to 25 by counting groups of rows with five objects).

Children learn from UMIGO upon first encounter. Children randomly assigned to the UMIGO treatment condition in both Wave One and Wave Two did not benefit from exposure to UMIGO in Wave Two more than children who initially encountered in UMIGO in Wave Two. This suggests that UMIGO components were sufficiently independent and intuitive. Children could learn from the Transmedia Suites without substantial prior experience in using UMIGO.

Lack of effects on affinity for mathematics. Because educational media need to compete with other forms of entertainment, the UMIGO transmedia property is designed to provide a user experience that is engaging, reinforcing, and builds the user's sense of competence. Although UMIGO is not explicitly intended to change attitudes regarding mathematics, it was considered that a positive experience with UMIGO might generalize to a broader affinity for mathematics. This was not the case. Affinity for math did not increase over time in either the UMIGO treatment or control conditions.

Young school children's attitudes towards mathematics are primarily shaped by their classroom experience and their interactions with their teacher. Children think of math within a classroom context, and may be less aware of how mathematics applies to other domains of their life. Although UMIGO teaches math content, it is not explicitly labeled as "math"; the activities are by design integrated and embedded into the ongoing narrative.

Directions for Future Research

The overall goal of RTL is to develop educational media that engenders early childhood learning. The Summative Evaluation B provides valuable insight into the potential of educational transmedia. Specifically, UMIGO provides for the foundation of an educational intervention in the form of online interactive storytelling. The significant gain by the UMIGO treatment group in skills and knowledge of 2D Geometric Shapes shows that UMIGO engenders learning. Specific instructional strategies and curricular content could be considered more explicitly in future

research to improve effectiveness by complementing, rather than duplicating, the instruction children receive in school.

Transmedia in the digital age presents a unique opportunity for engaging children in active non-mediated learning. Classroom instruction typically involves a combination of modeling, guided instruction, and practice. Educational television programming teaches through modeling by appealing characters within a compelling narrative, but it provides little opportunity for practice. Educational video games allow for practice through drill exercises and immediate individualized feedback, but often without an engaging narrative or characters.

The interactive transmedia prototyped by UMIGO combines modeling, problem solving, practice, and feedback within a compelling narrative with engaging characters. It is possible that Transmedia Suite 4 (Shapes) was most effective because it successfully integrated these four elements of instruction within the context of an interactive narrative adventure – the children were learning by doing (i.e. problem-solving by manipulating spatial objects) and receiving immediate reinforcing feedback in a story in which they were the protagonist.

The RTL grant was not specifically designed to fund basic research on media-facilitated learning processes. However, educational transmedia could benefit from additional research on how different teaching methods can be used within interactive narrative structures of transmedia to promote learning. For example, research can compare the effectiveness of teaching Shapes through modeling alone (watching characters manipulate shapes to solve puzzles), through practice and feedback outside the context of a narrative (solving puzzles on one's own), through modeling followed by practice, and by modeling and practice embedded within a storyline (interactively solving problems as part of a story in which the child becomes the protagonist).

Similarly, educational transmedia would benefit from more research on the optimal combination and integration of different media to promote learning. The Summative Evaluation B results show that the learning of Shapes was associated with the amount of time children spent engaging with the appisode of Transmedia Suite 4, but not the amount of time they spent

playing the multi-level game or watching the music video. This could be interpreted to suggest that only the appisode of Transmedia Suite 4 was important to learning. However, it is possible that the multi-level game and video might have had indirect effects by increasing children's engagement and interest, thereby prompting them to spend more time with the appisode. There is a need for more sophisticated planning of transmedia curricula to specify (and test) which learning tasks are best achieved through different media platforms.

Additionally, there is little empirical literature to determine the optimal dosage and testing timeline of media components. Children's spontaneous use of digital media typically involves short periods of engagement rather than a long extended lesson. Future research could explore what types of content can be mastered through brief, repeated exposures; how to best optimize learning in this context; what minimum dose of interaction is necessary for learning to occur; and how parents monitor the interaction and assure accurate records of usage.

In summary, the four UMIGO Transmedia Suites tested in Summative Evaluation B produced greater educational gains than activity-as-usual in one curriculum domain (2D Geometric Shapes), and supported learning in three (Measurement, Addition, and Skip Counting). This demonstrates that educational transmedia properties can produce incremental gains in understanding of mathematics concepts beyond what elementary school students learn through their usual activities, and the effectiveness of transmedia tools depends on a variety of factors. More theory-driven research is needed to inform our use of educational transmedia tools for instruction. Future research can identify what curriculum content areas are optimal for transmedia based learning, develop and test novel instructional approaches that complement rather than duplicate classroom instruction, and determine how to synergistically integrate different media platforms and learning components to optimize user engagement and learning.

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