Evaluating the Impact of the Investing in Innovation Fund (i3) UPSTART Project on Rural Preschoolers' Early Literacy Skills

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Abstract

UPSTART is a federally funded i3 validation project that uses a computer-based program to develop the school readiness skills of preschool children in rural Utah. Researchers used a randomized control trial design to evaluate the impact of the program in advancing children's early literacy skills. Preschoolers in the experimental group were randomly assigned to the UPSTART Reading software, while control group students were assigned to UPSTART Math. Standardized early literacy assessments were administered prior to program commencement and upon completion. Results revealed that there was a significant difference in children's mean scores on measures of letter knowledge and phonological awareness, after controlling for prior knowledge, missing pre-test data, and children's school district between those who participated in UPSTART Reading and those in the comparison group. There were no differences between the two groups on assessments measuring vocabulary and oral language or listening comprehension.

Impact of UPSTART Reading Participation for Rural Students While Controlling for Prior Reading Achievement and School District

The pathway to fluid reading begins with the development of preliteracy skills, such as concepts of print, alphabet knowledge, and phonological awareness, and progresses to reading words and text comprehension. A key precursor of literacy acquisition is phonological awareness, the ability to recognize, identify, and manipulate the smaller sound units within words, independent of their meaning (Cassady & Smith, 2004). Another crucial early literacy skill is letter knowledge, or the knowledge of the names and sounds associated with printed letters.

Research has consistently linked these early literacy skills with later reading achievement in school. Emergent readers who demonstrated phonemic blending and segmenting skills were found to be significantly more likely to successfully acquire beginning reading skills (Bauserman, Cassady, Smith, & Stroud, 2005). The National Early Literacy Panel (NELP) conducted a large-scale meta-analysis of early literacy research and found that emergent literacy skills such as phonological awareness and alphabet knowledge had a clear and consistently strong relationship with later reading skills, in addition to conventional literacy skills such as decoding, oral reading fluency, and comprehension that were also predictors of later achievement (NELP, 2008). Similarly, an analysis of six longitudinal datasets indicated that early language skills such as vocabulary, letter knowledge, and word sounds were a consistent predictor of later reading achievement, along with math and attention skills (Duncan et al., 2007).

Students who enter kindergarten with early literacy skills and are ready to learn get better grades, are more likely to graduate from high school, and have a greater chance of entering successful careers as adults than children who are less ready when they begin kindergarten (Reynolds et al., 2007). Conversely, young children who struggle with reading in early elementary school tend to fall behind their peers and perform at lower levels later in school.

High-quality early education settings that use age-appropriate curricula with clearly articulated goals can contribute to improvements in academic areas such as literacy and numeracy so that children have the skills for academic success at school entry (Phillips et al., 2017). While there is evidence that children from all socioeconomic backgrounds can benefit from early education programs, program effects tend to be higher and learning improvement greater for socioeconomically disadvantaged children (Barnett, 2008; Benner, Thornton, & Crosnoe, 2017; Phillips et al., 2017).

Although a large body of research points to the benefits of high-quality early education in fostering children's cognitive and emotional skills in preparation for the increasing rigor of formal education (Bakken, Brown, & Downing, 2017; Council of Economic Advisers, 2015; Duncan & Magnuson, 2013; Ramey & Ramey, 2004; Yoshikawa et al., 2013), children living in rural communities are less likely to participate in formal early education programs than children living in urban areas (Temple, 2009). Children reared in rural environments are more likely to live in lower income families compared to children living in urban environments (Addy, Englehardt, & Skinner, 2013) and may have limited access to high-quality preschools (Khan, Justice, & Jiang, 2016). Early education opportunities can prepare children for school, but researchers report that about 15% of children in rural communities attend a high-quality pre-kindergarten program, compared to 30% of children in urban and suburban areas (Nores & Barnett, 2014). Such disparities in early childhood education opportunities for rural children may be directly connected to recent findings from the Early Childhood Longitudinal Study that show that kindergarteners in rural communities perform more poorly than suburban and urban kindergartners on measures of math and reading (Miller & Votruba-Drzal, 2013).

Education Technology for the Underserved

Education technology offers an opportunity for rural children to receive early education instruction even in the face of limited center-based offerings or remote geographical locations. Technology is becoming a regular part of everyday life for many young learners and its use is increasing as a social and educational phenomenon (Laidlaw & Wong, 2016). Two-thirds of preschool-aged children actively engage with computer related technologies (National Center for Educational Statistics, 2005) and access to the internet in educational settings increased from 51% to 94% from 1998 to 2005 (NCES, 2008).

However, in spite of the adoption of new technologies such as smartphones and personal tablets, there is a persistent digital divide between urban and rural users, reminiscent of the disparity between rural and urban children's participation in early education settings. In their work with the National Telecommunications and Information Administration (NTIA), Carlson and Gross (2016) report that 69% of rural residents in 2015 reported internet use compared to 75% of urban residents. Moreover, Carlson and Gross note that the digital divide between urban and rural residents was evident with rural families with low incomes, with 66% of rural residents with family incomes between $25,000 and $49,999 reporting internet use, compared to 70% of their urban counterparts with similar income levels.

Recognizing these disparities, broadband grant programs funded by the American Recovery and Reinvestment Act of 2009 invested approximately $4 billion in projects to support and enhance broadband infrastructure throughout the United States and promote statewide broadband planning (NTIA, 2018). With the increasing adoption of widespread broadband connectivity, educational technologies can bridge the gap in high quality pre-kindergarten programs in rural communities where access to early learning curriculum is hindered by a lack of resources and geographical barriers (Smith, Patterson, & Doggett, 2008). To that end, there has been an abundance of educational software programs targeted to young learners, child care centers, parents, and schools to support the development of children's early literacy and reading skills (Wood, et al., 2012)

To date, positive findings for the use of reading software have been reported in the literature, creating a growing evidence base that children's lives can benefit from educational technology. A review of forty-two studies of computer-assisted instruction with beginning readers showed a positive overall effect size (d = .19) (Block, Ooststdam, Otter, & Overmat, 2002). Similarly, kindergarten students receiving computer-assisted instruction in phonological awareness and letter-sound correspondence had significantly higher scores on post-test measures of phonological awareness than children who did not receive computer instruction (Macaruso & Walker, 2011). Work by Abrami, Borohkovski, and Lysenko (2015) demonstrated that a computer-based reading program had significantly positive effects on children's phonological awareness, listening comprehension, and vocabulary knowledge. There was a positive relationship between exposure to educational technology curriculum during the course of the preschool day on children's school readiness, and these benefits were enhanced by children's additional computer experience at home (Li, Atkins, Stanton, 2006).

Although sporadic research on educational technology programs has been conducted in the past, researchers describe limited formal evaluation on software programs prior to release or once they are available to the general public (Grant et al., 2012) and when research is conducted, it often fails to meet methodological standards for high-quality research such as using adequate comparison groups, including implementation results, or providing the necessary data to determine effect sizes (Murphy, Penuel, Means, Korback, Whaley, & Allen, 2002). Moreover, although there are numerous educational software programs with the objective of helping children learn how to read, there is no regulatory body that screens software programs for educational value or quality (Willouhby & Wood, 2008).

Noting these trends in educational technology and the need for rigorous research to measure its impact, the U.S. Department of Education identified educational programs that serve rural communities and instructional solutions that effectively use technology as two of the most pressing priorities for education researchers in the 2013 i3 Notice of Final Priorities, Requirements, Definitions, and Selection Criteria. The Evaluation & Training Institute (ETI) partnered with the Department of Education and the Waterford Research Institute (i3 grantee) to study the effects of the UPSTART program on the emerging literacy skills of children living in rural districts throughout Utah.

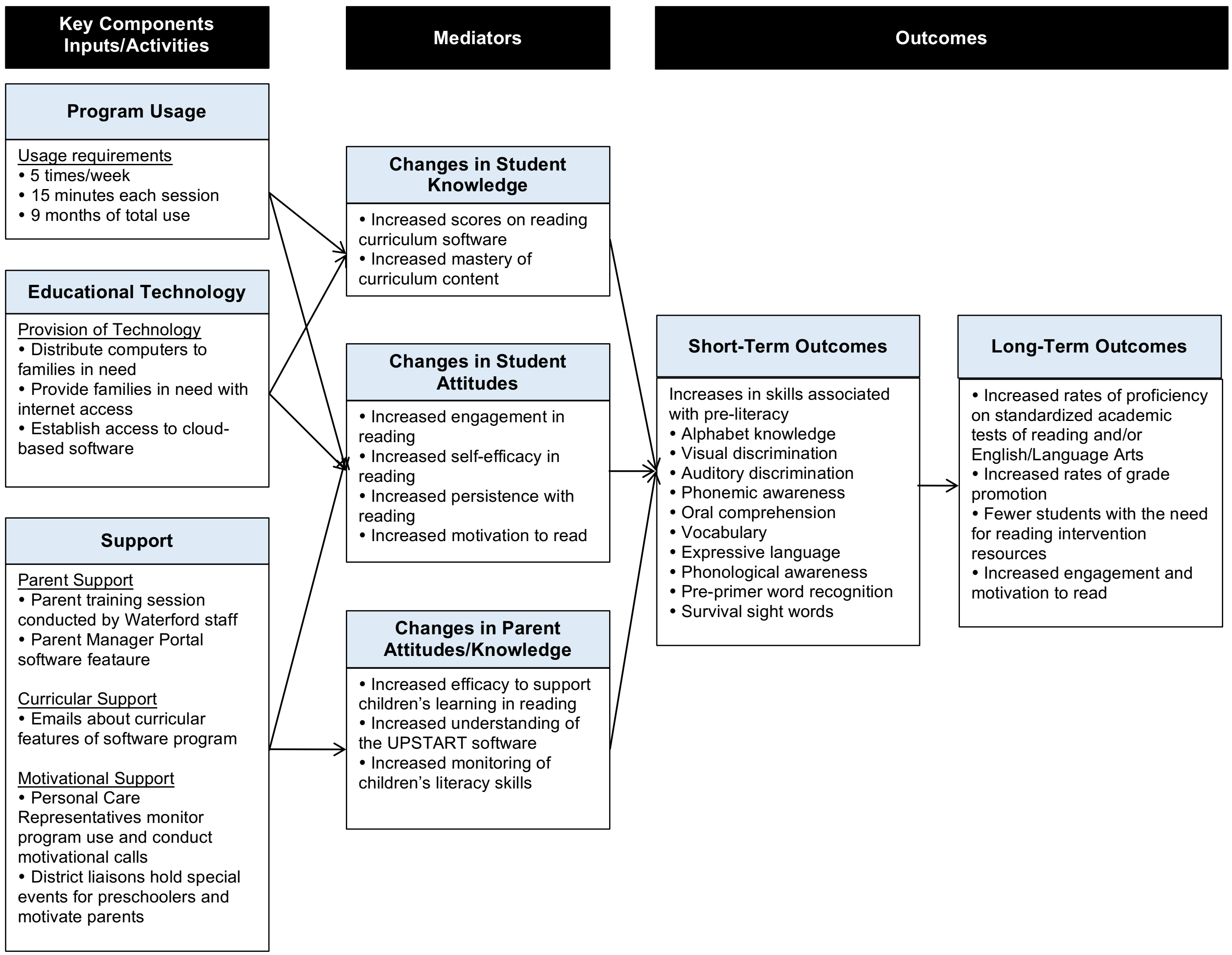
Learning Technology Under Study

UPSTART is a school readiness program that uses a home-based educational technology model with supportive resources that is well-suited to preschoolers and families residing in rural communities. The objective of UPSTART is to provide service to students in traditionally underserved rural areas, foster early cognitive growth, close reading achievement gaps, and increase school readiness at entry to kindergarten.

The logic model shown in Figure 1 illustrates the key components of the Rural UPSTART project, the mediators through which the intervention is designed to work, and the short- and long-term outcomes. While the UPSTART adaptive educational software is the core component of the program, the provision of technology in the form of computer hardware and/or high-speed internet ensure equitable access for all. Additionally, UPSTART families are provided with technical, motivational, and curricular support to encourage program software usage and facilitate the academic supervision of children by parents.

Figure 1

Rural UPSTART Project Logic Model



The principal component of UPSTART is an in-home computer-based school readiness software program that provides preschool children with reading, math, and science curriculum, with a focus on reading instruction. The program is designed to promote mastery of literacy and math skills that will prepare young children for entry into school by providing an individualized learning experience through a lesson sequencer that adapts to each child's skill level. Based on student performance, the sequencer will run remedial activities to reteach and practice skills again or advance to another objective if students are mastering concepts. Content is delivered online through lessons that adapt to a child's skill level, using multimedia, digital books, songs, and other online activities. Recommended usage of the software is 15 minutes a day, 5 days a week.

Based on early reading instruction guidelines outlined by the National Reading Panel (2008) that emphasize phonemic awareness, phonics, fluency, comprehension, and vocabulary, the UPSTART Reading program is designed to use research-based best practices for early literacy instruction. The UPSTART Reading curriculum seeks to lay the foundation for skilled reading by emphasizing precursor skills related to decoding and comprehension, two processes that are the hallmark of reading fluency (Hoover and Gough, 1990). Table 1 showcases the reading domains and skills taught by UPSTART Reading at the first level[1] of the curriculum: phonics, comprehension/vocabulary, language concepts, and phonological awareness.

[1] Level One is the beginning point of the curriculum where the preschool child begins as a nonreader and is introduced to skills designed to teach the child to read. Levels range from one to three and the child is tested at the beginning of the program and placed in a level based on his or her performance.

Table 1: *UPSTART Reading Program Domains and Skills*

UPSTART Reading Domains	Level 1 Reading Skill
Phonics Systematically builds from not reading to confident reading at 90 words a minute	• Recognize *A* through Z, and *a* through *z* • Learn 10 letter sounds and 20 sight words to read 10 leveled readers • Spell child's name
Comprehension/Vocabulary Develops vocabulary and critical thinking skills through rich reading experiences	• Read along and understand nursery rhymes • Read along and understand alliterative books • Learn 255 target vocabulary words
Language Concepts Introduces concepts of written language (from letters and pictures to basic grammar)	• Understand print (left-to-right, letters, pictures, words, text) • Develop oral language skills (colors, shapes, numbers, sizes, etc.)
Phonological Awareness Develops awareness of individual sounds in words	• Break words into individual sounds (cat to (/*k*/ /*a*/ /*t*/) • Blend individual sounds into words (/*k*/ /*a*/ /*t*/ to cat) • Change a sound in a word to make a new word (cat to bat)

Research Question and Hypothesis

We designed a randomized control-trial (RCT) experiment to test our primary research question:

> Do preschool children randomly assigned to receive the UPSTART Reading software program for one year have higher scores than their counterparts assigned to the UPSTART Math/Science program on the following measures of emerging literacy:
>
> a. Pre-literacy discrimination
>
> b. Letter knowledge,
>
> c. Phonological awareness,

d. Decoding,

e. Vocabulary and oral language, and

f. Listening comprehension?

We hypothesized that if the UPSTART Reading program has no effect on improving early literacy skills, then we would expect children who participated in UPSTART Reading (treatment group) to perform at the same level as children who received the Math/Science program (control group) on measures of early literacy. Conversely, if UPSTART Reading influences early literacy, then children in UPSTART Reading should perform significantly better than the comparison group on literacy outcomes.

Methods

Participants

All eighteen rural school districts in the state of Utah participated in the UPSTART program. Within each school district the program was offered to all age-eligible English-speaking children. Five of the smaller districts (Daggett, Piute, Rich, Tintic, and Wayne) were excluded from the preschool study due to insufficient sample size and geographical constraints. All families who registered for the UPSTART program and resided in the 13 target school districts were contacted by ETI. During this initial interaction, we described the evaluation in detail, established whether or not the family was interested in participating, conducted a screening to determine evaluation eligibility, and if the family was eligible, assigned the parent and child to a testing session. Program families were excluded from the evaluation if their child did not speak English or had a diagnosed learning disability.

Participants were 491 preschoolers from 13 rural Utah school districts who enrolled in the UPSTART program, sampled from a total UPSTART program group size of approximately 655 eligible families (roughly 75% of the total program group size at the start of testing.) Preschoolers were randomly assigned to the UPSTART Reading program ($N = 252$) and to UPSTART Math ($N = 239$) within districts.

Measures

Evaluation participants were administered two early literacy instruments to obtain baseline data: the Literacy scale of the Academic Skills/Cognitive Development component of the Brigance Inventory of Early Development III (Brigance, 2013) and the Preschool Early Literacy Indicators (PELI) (Dynamic Measurement Group, 2014). Table 2 presents the early literacy domains of interest, along with the corresponding literacy subtest used to measure children's abilities.

Table 2: *Literacy Domains by Instrument Subscale*

Early Literacy Domain	Instrument	Subscale
Pre-literacy	Brigance IED III	Visual Discrimination Auditory Discrimination
Letter knowledge	Brigance IED III	Recites Alphabet Names Uppercase Letters
Phonological awareness	Brigance IED III	Phonological Awareness Phonemic Manipulation
	PELI	Phonological Awareness (First Word Sounds/Parts)
Decoding	Brigance IED III	Word Recognition Reads Words from Common Signs
Vocabulary/Oral Language	PELI	Vocabulary and Oral Language
Listening comprehension	PELI	Listening Comprehension

Children's letter knowledge was assessed with the *Names Uppercase Letters* subtest from the Brigance, a 26-item scale that ranging from 1 to 26, and asks children to name all twenty-six letters of the alphabet. Phonological awareness was measured by the *Phonemic Manipulation* subscale of the Brigance (7-item scale ranging from 0 to 7) and the *Phonological Awareness* subscale of the PELI (10-item scale ranging from 0 to 15). While the Phonemic Manipulation subscale measures children's abilities to blend phonemic sounds into whole words and segment words into separate parts, the Phonological Awareness subscale assesses children's ability to identify the initial sounds and initial word parts of words. The *Vocabulary and Oral Language* subscale assessed children's ability to name, describe, and identify key elements of a picture related to a theme and consisted of a 15-item scale with scores that ranged from 0 to 35. Children's listening comprehension was measured with the PELI *Listening Comprehension* subtest (14-items, ranging from 0 to 23) that assessed children's ability to make predictions and inferences, answer comprehension questions related to a simple story, and to orally fill in the missing words of a story summary.

Design and Procedures

An intent-to-treat randomized control trial design was used (diagrammed in Figure 2), and included pre- and post-program early literacy measures administered to a group of treatment students (UPSTART Reading) and a group control students (UPSTART Math), who were randomly assigned to their condition within school districts prior to using the program.

Figure 2: *The Evaluation Design of the Preschool Study*

Summer 2014			Summer 2015	
Pre-Test	Random Assignment	UPSTART Reading Treatment	Post-Test	Kindergarten
Pre-Test		UPSTART Math Control	Post-Test	

Children were recruited to participate in the evaluation in the early summer of 2014. Children in both groups completed their respective programs over a nine-month period and post-program literacy assessments were conducted after the UPSTART program was completed in Summer 2015, just before the children entered kindergarten.

Assessments were individually administered to children by trained test administrators who were unaware of children's assignment to the treatment or control group and assessments were held at central locations within each district (e.g., elementary schools, libraries, community centers). The entire assessment procedure was completed in 30-40 minutes on average and was collected during the same period and with identical procedures for both groups.

Data Analytic Approach

We examined students' baseline characteristics to confirm that treatment and control groups were equivalent at pre-test on factors that may influence emergent literacy skills measured at kindergarten, such as initial differences between the two groups (e.g., pre-test achievement scores), as well as demographic factors that may differentiate between the treatment and control groups and found no statistically significant differences.

We begin by presenting pre-test and post-test mean scores by treatment group for each outcome measure in the Results section. Using independent samples *t*-tests, we established equivalence between the treatment and control group at pre-test, and determined if there are any significant differences between the two groups on post-program outcome measures. Mean differences upon program completion (at post-test) are presented, along with *t*-values and significance levels.

In order to control for factors that may influence our outcome variables of interest other than the treatment variable, we conducted a series of linear regressions for each outcome variable. Prior knowledge is an obvious control variable, and baseline data were collected before children began UPSTART Reading instruction on all outcome variables of interest. These pre-test measures were identical to the measures used to measure outcome data after a year of UPSTART Reading instruction was complete. Although preschoolers were randomly assigned to the treatment (UPSTART Reading) and control (UPSTART Math) conditions, assignment was within thirteen school district blocks (see Table 3). To adjust for unequal allocation to the treatment and control conditions within districts, we added dichotomous dummy variables that differentiated the district subsamples.

Table 3: *Number of Participants by School District*

District	Reading	Math	Total
Beaver	13	19	32
Duchesne	39	35	74
Emery	23	20	43
Garfield	11	10	21
Grand	9	9	18
Kane	17	16	33
Millard	21	15	36
North Sanpete	25	23	48
North Summit	5	7	12
Sevier	20	22	42
San Juan	14	13	27
South Sanpete	32	29	61
South Summit	23	21	44
Total	252	239	491

Missing Data

In an ideal world, all children who were pre-tested would have been post-tested. However, as in most longitudinal studies that rely on repeated measures, that ideal is rarely attained. Pre-tests were administered to 549 children (285 assigned to the Reading treatment condition and 264 assigned to the control condition), and 491 students completed a post-test one year later (252 children enrolled in UPSTART Reading and 239 children enrolled in UPSTART Math). Based on these numbers, the study had an overall attrition rate of 11% and a differential attrition rate of 2% (see Table 2). According to standards set by What Works Clearinghouse (2017), an overall attrition rate of 11% must have a differential attrition rate of less than 6% to have a tolerable threat of bias under both optimistic (i.e., attrition is exogenous or unrelated to the intervention) and cautious (i.e., attrition is endogenous or related to the intervention) assumptions regarding the relationship between attrition and outcomes. Attrition rates in Table 4 show that overall and differential attrition between treatment and control students was within acceptable levels of bias set by What Works Clearinghouse (2017), that threats from selective attrition were minimized (Miller & Hollist, 2007), and that our RCT was intact after post-program data collection.

Table 4: *Number of Participants in Evaluation Sample*

Group	Reading	Math	Total Sample
Children Pre-Tested	285	264	549
Children Post-Test	252	239	491
% Attrition	12%	10%	11%

Statistical Analysis

Following the recommendations outlined in What Works Clearinghouse (2017) and Puma, Olsen, Bell, and Price (2009), we set missing pre-test scores to a missing value constant and added a missing data flag to the regression model. For cases with missing post-test data, we used case deletion to remove those cases from our analytic sample and marked the missing cases as attrition.

With these considerations in mind, we define the following variables for each preschool student in linear regressions to estimate the impact of UPSTART reading on our outcome variables of interest: Y_{ij} is the preschooler's score on post-test literacy measures of letter knowledge, phonological awareness, oral language/vocabulary, and listening comprehension; Treatment (T_{ij}) is an indicator for whether the preschooler received the intervention (Treatment = 1 if the student was randomly assigned to the UPSTART Reading treatment intervention, Treatment = 0 if the preschooler was randomly assigned to the UPSTART Math control condition); $Y^{Pre}{}_{ij}$ is the preschooler's score on pre-test literacy measures (pre-test covariate); $Y^{MissingPre}{}_{ij}$ is an indicator for records with missing pre-test data; and $Block_j$ is a district block dummy covariate and indicates whether or not a preschooler resided in one of the thirteen specific school districts while participating in the UPSTART Reading and Math programs. One possible linear regression model that uses these variables is the following:

$$Y_{ij} = \beta_0 + \beta_1(T_{ij}) + \beta_2(Y^{Pre}{}_{ij}) + \beta_3(Y^{MissingPre}{}_{ij}) + \sum_{j=1}^{J-1} \gamma_j Block_j + \varepsilon_{ij}$$

The βs in Eq. 1 are regression coefficients that describe the relationship between each variable and the preschooler's post-test score:

- β_0 is the intercept;
- β_1 is the expected increase in the post-test score for preschoolers who participated in the UPSTART Reading intervention relative to students who did not receive the intervention.
- β_2 is the effect of pre-test data;

- β_3 is the effect of having missing data at pre-test;
- β_4 through β_{15} are fixed block dummy variables to measure district effects.

Separate linear regressions were run to estimate the effects of our outcomes of interest: letter knowledge, phonological awareness (first word sounds and phoneme manipulation), vocabulary/oral language, listening comprehension.

Results

Preliminary Results. Table 5 presents pre-test and post-test mean scores on the early literacy constructs of interest: pre-literacy discrimination, letter knowledge, phonological awareness, decoding, vocabulary/oral language, and listening comprehension. Initial results from *t*-tests indicate that there were no significant pre-program differences between children assigned to treatment and control conditions on any subscale, indicating comparable levels of early literacy skills between the two experimental groups prior to beginning the UPSTART program. There were, however, significant post-program differences between children enrolled in UPSTART Reading and those participating in UPSTART Math on measures of letter knowledge [identifying uppercase letters ($t(489) = 6.09$, $p = .000$) and reciting the alphabet ($t(489) = 2.86$, $p = .004$)]; phonological awareness [phonological awareness ($t(489) = 2.25$, $p = .025$), phoneme manipulation ($t(489) = 3.58$, p = .000), and initial word sounds ($t(489) = 3.20$, $p = .001$)]; and decoding [word recognition ($t(489) = 5.67$, $p = .000$) and reading words from common signs ($t(489) = 2.85$, $p = .005$)], with UPSTART Reading children outperforming their Math counterparts. There was no significant difference between groups at post-test on measures of pre-literacy discrimination [visual discrimination ($t(489) = .96$, $p = .339$), auditory discrimination ($t(489) = .37$, $p = .709$)]; vocabulary and oral language ($t(489) = -.37$, $p = .710$); or listening comprehension ($t(489) = .70$, $p = .486$).

Table 5: *Subscale Pre-Test and Post-Test Means of Treatment-Control Groups by Literacy Construct*

	Pre-test				Post-Test			
Subscale	*N*	Mean	*SD*	*t*-value	*N*	Mean	*SD*	*t*-value
Pre-literacy								
Visual Discrimination								
Reading	247	11.63	5.449	1.32	252	16.59	3.204	.96
Math	235	10.96	5.654		239	16.33	2.915	
Auditory Discrimination								
Reading	247	6.47	2.543	1.34	252	7.79	2.693	.37
Math	234	6.16	2.473		239	7.70	2.458	
Letter Knowledge								
Recites Alphabet								
Reading	246	7.51	9.051	.36	252	19.39	9.074	2.86**
Math	230	7.23	8.302		239	16.91	10.132	
Identifies Uppercase Letters								
Reading	247	9.23	8.862	.75	252	20.53	7.106	6.09**
Math	233	8.61	9.099		239	16.19	8.634	
Phonological Awareness								
Phonological Awareness								
Reading	248	4.49	2.484	1.33	252	6.57	2.444	2.25*
Math	233	4.19	2.532		239	6.06	2.564	
Phoneme Manipulation								
Reading	246	2.46	1.339	.44	252	4.07	1.529	3.58**
Math	233	2.40	1.453		239	3.56	1.631	
Initial Word Sounds								
Reading	242	4.69	4.643	-.22	252	10.53	4.673	3.20**
Math	232	4.79	4.813		239	9.19	4.592	
Decoding								
Word Recognition								
Reading	242	.27	1.419	.56	252	3.38	3.997	5.67**
Math	230	.21	.793		239	1.50	3.288	
Reads Words from Signs								
Reading	244	1.09	1.360	.61	252	2.25	1.951	2.85*
Math	231	1.02	.872		239	1.75	1.969	
Vocabulary/Oral Language								
Vocabulary/Oral Language								
Reading	248	16.96	6.851	-.18	252	22.48	6.197	-.37
Math	234	17.08	6.820		239	22.68	6.043	
Listening Comprehension								
Listening Comprehension								
Reading	245	14.97	4.403	1.06	252	18.36	3.642	.70
Math	232	14.53	4.729		239	18.14	3.429	

Linear Regression Analysis

Ordinary least squares multiple regression models were conducted to examine the relationship between the outcome variables of interest and potential predictors, including treatment status, baseline literacy scores at pre-test, district blocking variables to control for unequal allocation to the treatment and control conditions within districts, and a dummy variable adjustment to control for missing pre-test data. Summaries of results without the district blocking variables are presented by literacy construct. The full regression models are included in Appendix A.

Pre-literacy discrimination. Two separate multiple regressions were conducted with visual discrimination and auditory discrimination scores as dependent variables and treatment group membership, pre-test baseline scores, school district, and missing pre-test data as predictor variables. Table 6 presents the regression results for visual discrimination and auditory discrimination, respectively, and reveal that participation in the treatment condition (UPSTART Reading) did not have a significant impact on children's visual discrimination skills ($\beta = 0.02$, $p = .530$) or auditory discrimination ($\beta = 0.01$, $p = .828$)

Table 6: *Regression Summary of Predictors of Pre-Literacy Discrimination*

	Visual Discrimination (N=482)			Auditory Discrimination (N=481)		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*
(Constant)	13.75	0.54		6.67	0.54	
Treatment	0.15	0.25	0.03	0.05	0.22	0.01
Pre-Test	0.20	0.02	0.38	0.23	0.05	0.23
Missing Pre-Test Data	-0.95	0.88	-0.05	-3.48	0.81	-0.19
R^2	0.22			0.14		
F	8.85			5.00		

* p<0.05; ** p<0.01

Letter Knowledge. To test the hypothesis that participation in UPSTART Reading had a unique positive impact on preschoolers' letter knowledge controlling for prior knowledge, school district, and missing pre-test data, a regression analysis was performed. Results of the regression analyses displayed in Tables 7 and 8 provided confirmation that UPSTART Reading had a positive influence on children's alphabet knowledge. The ability to identify uppercase letters had a significant beta coefficient for the treatment predictor ($\beta = .25$, $p = .000$), indicating that participation in UPSTART had a significant impact on children's letter knowledge while controlling for prior knowledge, missing pre-test data, and school district. On the second letter knowledge measure that assessed children's capacity to recite the alphabet, assignment to the treatment condition was a small, but significant predictor of children's scores ($\beta = .10$, $p = .017$).

Table 7: *Regression Analysis of Predictors of Letter Knowledge*

	Uppercase Letter Knowledge (N=480)			Recites Alphabet (N=476)		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*
(Constant)	10.80	1.13		11.25	1.73	
Treatment	4.04	0.54	0.25**	1.97	0.82	0.10*
Pre-Test	0.55	0.03	0.62**	0.28	0.05	0.25
Missing Pre-Test Data	-0.73	2.13	-0.01	-0.54	4.61	-0.01
R^2		.48		0.16		
F		28.68**		5.62		

* p<0.05; ** p<0.01

Phonological Awareness. Three separate regressions, one predicting preschoolers' phoneme manipulation skills, the second predicting initial sound phonological awareness, and the third measuring general phonological awareness (e.g., segmenting and blending word parts, rhyming) were conducted to measure the impact of participating in UPSTART Reading are displayed in Table 8. Each regression included covariates to control for pre-test performance, missing pre-test data, and school districts. Results showed that UPSTART Reading enrolment had a unique and positive impact on phonemic manipulation (β = .16, p = .000) and on initial word sounds phonological awareness (β = .15, p = .000), but not on general phonological awareness scale (β = .07, p = .080) that measured the ability to blend, segment and rhyme words.

Table 8: *Regression Analysis of Predictors of Phonological Awareness (PA)*

	Phoneme Manipulation (N=479)			*Initial Word Sounds PA (N=496)*			*General PA (N=481)*		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*
(Constant)	2.43	0.28		6.22	0.75		5.28	0.46	
Treatment	0.51	0.13	0.16**	1.38	0.36	0.15**	0.36	0.20	0.07
Pre-Test	0.51	0.05	0.46**	0.47	0.04	0.49**	0.40	0.04	0.41
Missing Pre-Test Data	-0.52	0.54	-0.04	-6.98	2.77	-0.10*	-1.21	0.76	-0.67
R^2	.25			.31			.21		
F	10.37**			13.88**			8.22		

* p<0.05; ** p<0.01

Decoding. In order to determine the unique impact of the treatment condition on children's developing decoding capabilities, multiple regression analyses were conducted with decoding literacy scores as dependent variables and UPSTART Reading participation, decoding scores prior to beginning UPSTART, school district, and missing pre-test data as predictor variables. Results of the regression analyses displayed in Table 9 provide confirmation that UPSTART Reading had a significant positive impact on children's emerging decoding skills of word recognition and reading common signs. The ability to read or recognize basic pre-primer vocabulary words had a significant beta coefficient for the treatment predictor (β = .24, p = .000), indicating that participation in UPSTART had a significant impact on children's word recognition skills while controlling for prior knowledge, missing pre-test data, and school district. Similarly, assignment to the UPSTART Reading program had a significant contribution to children's capacity to read or recognize common signs in their everyday environments (β = .11, p = .007).

Table 9: *Regression Analysis of Predictors of Decoding*

	Word Recognition (N=491)			Common Signs (N=475)		
Variable	*B*	*SE B*	β	*B*	*SE B*	β
(Constant)	1.61	0.62		0.80	0.33	
Treatment	1.80	0.30	0.24**	0.43	0.16	0.11**
Pre-Test	1.54	0.13	0.46**	0.89	0.07	0.50**
Missing Pre-Test Data	0.00	0.00	0.00	-1.30	1.01	-0.05
R^2	0.31			0.27		
F	14.32			11.30		

* p<0.05; ** p<0.01

Listening Comprehension. To test the hypothesis that participation in UPSTART Reading had a unique positive impact on preschoolers' listening comprehension while controlling for prior knowledge, school district, and missing pre-test data, a regression analysis was performed. Results of the regression analysis did not confirm the hypothesis and indicated that participation in UPSTART did not have significant impact on children's listening comprehension, β = -0.01, p = .763 (Table 10).

Table 10: *Regression Analysis of Predictors of Listening Comprehension (N = 477)*

Variable	*B*	*SE B*	*β*
(Constant)	14.05	0.68	
Treatment	0.08	0.26	0.01
Pre-Test	0.25	0.03	0.34**
Missing Pre-Test Data	-3.18	1.28	-0.10
R^2	.31		
F	13.50**		

* p<0.05; ** p<0.01

Vocabulary and Oral Language. A multiple regression was used to test the hypothesis that participation in UPSTART reading had a positive impact on children's vocabulary and oral language skills was tested. Results displayed in Table 11 indicate that after controlling for pre-test scores, school district, and the presence of missing data, random assignment to UPSTART Reading did not have a significant impact on children's vocabulary and oral language, $\beta = -0.01$, $p = .681$.

Table 11: *Regression Analysis of Predictors of Vocabulary and Oral Language (N=482)*

Variable	*B*	*SE B*	*β*
(Constant)	17.06	1.01	
Treatment	-0.17	0.42	-0.01
Pre-Test	0.49	0.03	0.57**
Missing Pre-Test Data	-0.95	1.53	-0.02
R^2		.43	
F		23.21**	

* p<0.05; ** p<0.01

Effect Sizes. The effect size estimates are presented in Table 12 and show the magnitude of the average performance differences in standard deviation units between the treatment group and the control group on subscales measuring pre-literacy discrimination, letter knowledge, phonological awareness, decoding, vocabulary and oral language, and listening comprehension. Effect sizes were calculated based on the adjusted mean difference between the treatment and control groups divided by the unadjusted pooled standard deviation. The adjusted mean difference between the two groups was derived from the linear regression analysis and controlled for pre-test scores, school district, and the presence of missing data.

Table 12: *Post-Test Effect Size Estimates based on Adjusted Means*

Construct	Literacy Subscale	Effect Size
Pre-literacy skills	Visual Discrimination	.05
	Auditory Discrimination	.02
Phonological Awareness	Initial Sounds Phonological Awareness	.30**
	Phoneme Manipulation	.32**
	General Phonological Awareness	.14
Alphabet Knowledge	Identifies Uppercase Letters	.51**
	Recites Alphabet	.21*
Decoding	Word Recognition	.49**
	Reads Words from Common Signs	.22**
Vocabulary and Oral Language	Vocabulary and Oral Language	-.03
Listening Comprehension	Listening Comprehension	.02

*p<.05, **p<.01, ***p<.001

Overall, the UPSTART Reading program produced small to medium-size impacts on enhancing preschool children's alphabet knowledge, as measured by the ability to recognize uppercase letters (Hedges's g = .55) and recite the alphabet (Hedges's g = .21). Similarly, participation in the UPSTART Reading program resulted in statistically significant positive effects in phonological awareness skills such as phoneme manipulation (Hedges's g = .32) and identifying initial word parts and sounds (Hedges's g = .30). UPSTART Reading generated small to medium-size effects on children's emergent decoding abilities, as demonstrated with basic pre-primer vocabulary words (Hedges's g = .49) and on signs commonly seen in children's everyday environment (Hedges's g = .22).

There were no significant differences between children assigned to the UPSTART Reading condition with those assigned to UPSTART Math on subscales that assessed pre-literacy discrimination, vocabulary and oral language, and listening comprehension.

Discussion

While there has been some research on the effects of educational technology on young learners (Foster, Erickson, Foster, Brinkman, & Torgesen, 1994; Mitchell & Fox, 2001), researchers acknowledge that the field is still in its infancy (Glaubke, 2007), and that available educational software typically is not formally evaluated for effectiveness in teaching reading skills (Wood et al., 2012). Adding to the body of research on educational technology and early literacy instruction, results from this randomized design study show that the UPSTART Reading program has significant effects on rural young children's precursor literacy skills of phonological awareness (effect sizes ranging from .30 to .32), letter knowledge (effect sizes ranging from .21 to .51), and decoding (effect sizes ranging from .22 to .49).

Correlational studies have identified letter knowledge and phonological awareness as the two best predictors at school entry of how well children will learn to read during the first two years of instruction (National Reading Panel, 2000). As preschoolers enter kindergarten, the curriculum proceeds beyond letter recognition and phonological awareness to phonics instruction, which involves learning the grapheme-phoneme relationship, or the idea that letters correspond to sounds (Grant et al., 2012). Children who participate in UPSTART Reading during their preschool year are more likely to arrive at school with the prerequisite skills that contribute to future success.

The positive impact of UPSTART on children's letter knowledge, phonological awareness, and decoding skills stems from the program's utilization of a phonics-based reading program as part of its literacy curriculum which conforms to the National Reading Panel's (2000) recommendation that early readers benefit from an explicit systematic approach to reading instruction. Moreover, UPSTART's phonological awareness instruction adheres to the research-based practices outlined by Armbruster and colleagues at the National Institute for Literacy (2006), as it teaches children to use letters to manipulate phonemes as a precursor to decoding.

There were, however, no significant differences between the treatment and control group after controlling for prior knowledge, missing pre-test data, and school district on subscales measuring listening comprehension and vocabulary/oral language skills, key components of deriving meaning from text. Other early reading interventions analogous to UPSTART have similarly shown larger impacts aligned to explicit code-based reading instruction (alphabet knowledge, phonemic awareness, decoding) than for comprehension (Simmons et al., 2011)

It is possible that the UPSTART Reading curriculum failed to have an impact on children's oral language, vocabulary, and comprehension above and beyond exposure to print-rich environments or the naturalistic home practices (e.g., actively reading stories to children, engaging in back and forth conversation) common in our participating families, regardless of experimental condition. Abrami, Borokhobski, and Lysenko (2015) note that vocabulary teaching, in particular, is influenced by the richness of the reading context and the motivational value of the text for the reader.

The didactic presentation of vocabulary and e-book stories by the UPSTART program may also contribute to the lack of positive findings as other studies have pointed to the benefits of extended discussion between a preschooler and teacher during book reading sessions in building children's vocabulary and comprehension (Dickinson & Smith, 1994; Gonzalez et al., 2011). It appears as though UPSTART's benefits are more pronounced with the basic building blocks of reading that require direct and systematic instruction (i.e., recognizing letters, phoneme phonological awareness, decoding) as opposed to skills like vocabulary acquisition and oral language that are "hard wired" in children from birth and activated through reciprocal dialogue.

Lastly, our comparison group consisted of children who participated in UPSTART Math, an educational software program that was identical to UPSTART Reading, save the curricular content. It is possible that enrollment in UPSTART Math conferred some benefits in early literacy to children, as a meta-analytic results of longitudinal school entry data sets indicate that early math skills were a most powerful predictor of later achievement in both math and reading (Duncan et al., 2007).

The positive early literacy findings from children who participated in UPSTART Reading support previous research that suggest that rural students can benefit from focused and targeted literacy intervention (Amendum, Vernon-Feagans, & Ginsberg, 2011). More than 20 percent of all public school students in the United States are enrolled in rural school districts (Johnson, Showalter, Klein, & Lester, 2014), but these children are often overlooked in discussions of educational policy (Beeson & Strange, 2000). High-quality early education technology programs such as UPSTART that are readily accessible by families can be a viable pathway for preparing children in underserved areas to meet the demands of kindergarten and close the school readiness gap between rural children and their non-rural counterparts.

Previous research of computer-based instructional programs has shown that benefits are linked with sufficient program use (Macaruso & Rodman, 2011) and additional analysis is needed to determine if outcomes are stronger for students who meet the requirements for minimum program use of UPSTART Reading compared to children who do fulfill the recommended program use. Further research of the UPSTART Reading program will explore more nuanced questions, including the role of other factors such as preschoolers' motivation and engagement with the program, parental support, and general home literacy environment that may mediate or moderate the relationship between UPSTART Reading participation and early literacy outcomes.

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Appendix A

Full Regression Tables

Table A.1

Regression Analysis of Predictors of Visual Discrimination (N = 482)

Variable	*B*	*SE B*	*β*
(Constant)	13.75	0.54	
Treatment	0.15	0.25	0.03
Pre-Test	0.20	0.02	0.38
Missing Pre-Test Data	-0.95	0.88	-0.05
District 1	0.87	0.58	0.11
District 2	0.94	0.64	0.09
District 3	-1.33	0.76	-0.09
District 4	1.51	0.81	0.09
District 5	-0.21	0.68	-0.02
District 6	0.19	0.67	0.02
District 7	0.36	0.62	0.04
District 8	0.18	0.94	0.01
District 9	-0.04	0.64	-0.00
District 10	-0.64	0.72	-0.05
District 11	0.74	0.60	0.08
District 12	1.37	0.64	0.13*
R^2	0.22		
F	8.85		

* p<0.05; ** p<0.01

Table A.2

Regression Analysis of Predictors of Auditory Discrimination (N = 481)

Variable	*B*	*SE B*	*β*
(Constant)	6.67	0.54	
Treatment	0.05	0.22	0.01
Pre-Test	0.23	0.05	0.23
Missing Pre-Test Data	-3.48	0.81	-0.19
District 1	-0.62	0.51	-0.09
District 2	0.46	0.57	0.05
District 3	-0.76	0.68	-0.06
District 4	1.07	0.74	0.08
District 5	0.94	0.61	0.09
District 6	-1.04	0.59	-0.11
District 7	-0.67	0.55	-0.08
District 8	-2.09	0.84	-0.12*
District 9	-0.41	0.57	-0.05
District 10	-0.19	0.63	-0.02
District 11	-0.14	0.53	-0.02
District 12	-0.24	0.57	-0.03
R^2	0.14		
F	5.00		

* $p<0.05$; ** $p<0.01$

Table A.3

Regression Analysis of Predictors of Uppercase Letter Knowledge (N=480)

Variable	*B*	*SE B*	*β*
(Constant)	10.80	1.13	
Treatment	4.04	0.54	0.25**
Pre-Test	0.55	0.03	0.62**
Missing Pre-Test Data	-0.73	2.13	-0.01
District 1	0.80	1.27	0.04
District 2	-0.17	1.39	-0.01
District 3	-1.43	1.72	-0.04
District 4	0.66	1.81	0.02
District 5	2.25	1.49	0.07
District 6	0.52	1.45	0.02
District 7	2.77	1.36	0.10*
District 8	1.58	2.06	0.03
District 9	-1.25	1.40	-0.04
District 10	-0.33	1.55	-0.01
District 11	0.33	1.30	0.01
District 12	4.06	1.40	0.14**
R^2		.48	
F		28.68**	

* p<0.05; ** p<0.01

Table A.4

Regression Analysis of Predictors of Recites Alphabet (N = 476)

Variable	*B*	*SE B*	*β*
(Constant)	11.25	1.73	
Treatment	1.97	0.82	0.10*
Pre-Test	0.28	0.05	0.25
Missing Pre-Test Data	-0.54	4.61	-0.01
District 1	4.45	1.95	0.17*
District 2	6.30	2.14	0.19**
District 3	-4.69	2.59	-0.10
District 4	3.59	2.77	0.07
District 5	5.90	2.34	0.15*
District 6	4.19	2.23	0.12
District 7	4.42	2.10	0.14*
District 8	2.88	3.17	0.05
District 9	7.86	2.15	0.23
District 10	-0.66	2.40	-0.02
District 11	3.43	2.02	0.12
District 12	7.53	2.16	0.22**
R^2	0.16		
F	5.62		

* p<0.05; ** p<0.01

Table A.5

Regression Analysis of Predictors of Phoneme Manipulation (N = 479)

Variable	*B*	*SE B*	*β*
(Constant)	2.43	0.28	
Treatment	0.51	0.13	0.16**
Pre-Test	0.51	0.05	0.46**
Missing Pre-Test Data	-0.52	0.54	-0.04
District 1	0.06	0.30	0.01
District 2	-0.03	0.33	-0.01
District 3	-0.29	0.41	-0.04
District 4	-0.04	0.43	-0.01
District 5	-0.17	0.36	-0.03
District 6	-0.17	0.35	-0.03
District 7	-0.30	0.33	-0.06
District 8	-0.29	0.49	-0.03
District 9	0.29	0.33	0.05
District 10	0.16	0.37	0.02
District 11	0.20	0.31	0.04
District 12	-0.56	0.34	-0.10
R^2	.25		
F	10.37**		

* p<0.05; ** p<0.01

Table A.6

Regression Analysis of Predictors of Initial Word Sounds Phonological Awareness (N = 496)

Variable	*B*	*SE B*	*β*
(Constant)	6.22	0.75	
Treatment	1.38	0.36	0.15**
Pre-Test	0.47	0.04	0.49**
Missing Pre-Test Data	-6.98	2.77	-0.10*
District 1	-0.14	0.84	-0.01
District 2	3.18	0.92	0.20
District 3	0.41	1.14	0.02
District 4	-0.14	1.21	-0.01
District 5	2.10	1.01	0.11*
District 6	1.65	0.96	0.10
District 7	2.35	0.91	0.15
District 8	-0.76	1.37	-0.03
District 9	-0.67	0.93	-0.04
District 10	-1.48	1.04	-0.07
District 11	1.11	0.87	0.08
District 12	1.69	0.93	0.10
R^2	.31		
F	13.88**		

* p<0.05; ** p<0.01

Table A.7

Regression Analysis of Predictors of General Phonological Awareness (N = 481)

Variable	*B*	*SE B*	*β*
(Constant)	5.28	0.46	
Treatment	0.36	0.20	0.07
Pre-Test	0.40	0.04	0.41
Missing Pre-Test Data	-1.21	0.76	-0.67
District 1	-0.74	0.48	-0.11
District 2	0.67	0.53	0.08
District 3	-1.95	0.64	-0.16**
District 4	-0.36	0.69	-0.03
District 5	-0.54	0.56	-0.06
District 6	-1.72	0.55	-0.19**
District 7	-0.65	0.52	-0.08
District 8	-2.15	0.78	-0.13**
District 9	-1.46	0.53	-0.17**
District 10	-1.29	0.59	-0.12*
District 11	-0.70	0.49	-0.10
District 12	-0.46	0.54	-0.05
R^2	.21		
F	8.22		

* $p<0.05$; ** $p<0.01$

Table A.8

Regression Analysis of Predictors of Word Recognition (N = 491)

Variable	*B*	*SE B*	*β*
(Constant)	1.61	0.62	
Treatment	1.80	0.30	0.24**
Pre-Test	1.54	0.13	0.46**
Missing Pre-Test Data	0.00	0.00	0.00
District 1	0.03	0.71	0.00
District 2	-1.30	0.78	-0.10
District 3	-1.89	0.96	-0.10*
District 4	0.21	1.01	0.01
District 5	0.03	0.85	0.00
District 6	0.78	0.81	0.05
District 7	-0.63	0.77	-0.05
District 8	-1.25	1.15	-0.05
District 9	-1.30	0.78	-0.10
District 10	0.50	0.88	0.03
District 11	-0.26	0.74	-0.02
District 12	-0.29	0.79	-0.02
R^2	0.31		
F	14.32		

* p<0.05; ** p<0.01

Table A.9

Regression Analysis of Predictors of Common Signs (N = 475)

Variable	*B*	*SE B*	*β*
(Constant)	0.80	0.33	
Treatment	0.43	0.16	0.11**
Pre-Test	0.89	0.07	0.50**
Missing Pre-Test Data	-1.30	1.01	-0.05
District 1	0.29	0.38	0.05
District 2	0.08	0.41	0.01
District 3	-0.46	0.51	-0.05
District 4	0.04	0.54	0.00
District 5	0.27	0.45	0.03
District 6	-0.06	0.43	-0.01
District 7	0.44	0.41	-0.07
District 8	0.42	0.61	0.03
District 9	0.10	0.42	0.01
District 10	-0.11	0.46	-0.01
District 11	0.33	0.39	0.06
District 12	-0.26	0.42	-0.04
R^2	0.27		
F	11.30		

* p<0.05; ** p<0.01

Table A.10

Regression Analysis of Predictors of Listening Comprehension (N = 477)

Variable	*B*	*SE B*	*β*
(Constant)	14.05	0.68	
Treatment	0.08	0.26	0.01
Pre-Test	0.25	0.03	0.34**
Missing Pre-Test Data	-3.18	1.28	-0.10
District 1	-1.26	0.61	-0.14*
District 2	3.05	0.67	0.26**
District 3	-0.76	0.81	-0.05
District 4	1.08	0.88	0.06
District 5	2.33	0.73	0.17**
District 6	-1.26	0.70	-0.10
District 7	1.66	0.66	0.15*
District 8	1.36	0.99	0.06
District 9	2.21	0.67	0.19**
District 10	0.63	0.75	0.04
District 11	0.97	0.63	0.10
District 12	0.42	0.67	0.04
R^2	.31		
F	13.50**		

* p<0.05; ** p<0.01

Table A.11

Regression Analysis of Predictors of Vocabulary and Oral Language (N=482)

Variable	*B*	*SE B*	*β*
(Constant)	17.06	1.01	
Treatment	-0.17	0.42	-0.01
Pre-Test	0.49	0.03	0.57**
Missing Pre-Test Data	-0.95	1.53	-0.02
District 1	-3.96	0.98	-0.24**
District 2	-2.19	1.08	-0.11*
District 3	-2.91	1.29	-0.10*
District 4	1.27	1.41	0.04
District 5	-2.18	1.18	-0.09
District 6	-3.76	1.13	-0.17**
District 7	-0.84	1.07	-0.04
District 8	-1.75	1.56	-0.05
District 9	-5.57	1.09	-0.27**
District 10	-3.69	1.21	-0.14**
District 11	-1.71	1.02	-0.10
District 12	-3.06	1.09	-0.15
R^2		.43	
F		23.21**	

* p<0.05; ** p<0.01