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Improving Early Math Skills: Upstart Program Effects from Pre-Kindergarten to Kindergarten

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ABOUT EVALUATION AND TRAINING INSTITUTE

Founded in 1974, the Evaluation & Training Institute (ETI) is a non-profit consulting firm, headquartered in Los Angeles, dedicated to working with schools, post-secondary institutions, public agencies, private foundations, community-based organizations, and professional organizations. We specialize in third-party program evaluations covering many fields, including education, literacy, STEM, social services, health, and prevention. Many of our evaluations have been instrumental in the development of public policy as well as state and federal legislation. Throughout, our focus is on helping clients improve their programs as well as maintain accountability to funders and oversight committees.

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Abstract

Upstart is a computer-based program used to develop the school readiness skills of young children in the state of Nevada. Researchers used a randomized control trial design to evaluate the impact of the program on advancing children's early math skills. Pre-kindergarteners in the treatment group were randomly assigned to the Upstart math software, while control group students were assigned to the Upstart reading software. Standardized early math assessments were administered prior to program commencement, upon completion of the pre-kindergarten program, and then again at the end of kindergarten. Results revealed significant differences in children's mean scores on measures of math concepts and applications between those who participated in Upstart math and those in the comparison Upstart reading group. The treatment effects were observed following both the pre-kindergarten year and at the end of the kindergarten year. Hispanic children who were dual language learners (DLL) scored lower than monolinguistic children on measures of mathematical concepts at the end of pre-kindergarten and kindergarten, but significant interactions between DLL and treatment status were not found at either point in time. We have learned that developing an early math skillset is a critical part of school readiness, and these basic mathematical abilities provide a foundation from which more advanced skills develop. We have also learned that interventions can be successfully delivered through educational technology in the homes of pre-kindergarten students who may otherwise not have access to school readiness programs.

Improving Early Math Skills: Upstart Program Effects from Pre-Kindergarten to Kindergarten

The targeted outcomes of pre-kindergarten school readiness programs often include a mix of developmental milestones in the cognitive and social domains. Early literacy skills, in particular, have long been a dominant focus of pre-kindergarten prep programs, given the importance of learning to read. However, with recent national shifts in priority around STEM education, there is a growing body of research supporting the early development of numeracy skills as a means to boost school readiness, drive an early interest in STEM, and provide a foundation for more complex math learning ("*U.S. Department of Education launches new initiative*," 2022).

The importance of formally preparing children for kindergarten is now reflected in 44 states that fund pre-kindergarten programs (Friedman-Krauss et al., 2022), underscoring early childhood as the crucial window of opportunity for foundational skills, including math preparation. With a growing interest and the prioritization of STEM education, researchers in the field of early education have the opportunity to study the importance of early numeracy and how these early skills connect with a successful transition into school, influence later math learning, and serve as the basis for enhanced STEM engagement and interest.

Importance of Early Math in School Readiness

The benefits of an early math skillset are far-reaching, with longitudinal studies documenting improved readiness for school entry (Watts et al., 2014; Nelson & McMaster, 2019) and higher levels of academic and math achievement (Shanley et al., 2017; Terry, 2021; Watts et al., 2014). Basic numeracy skills learned prior to kindergarten, such as the ability to read 1-digit numerals, count beyond 10, and recognize a sequence of patterns, are found to be the most consistent and important predictors of test scores in both reading and math across elementary school (Nelson & McMaster, 2019; Litkowski et al., 2020; Terry, 2021). In addition to core numeric skills, research suggests that exposure to and use of mathematical language is a valuable targeted skill, particularly for pre-kindergarteners. Mathematical language is "content-specific language that consists of terms used to describe quantitative and spatial relations" (King & Purpura, 2021). More simply put, it introduces math vocabulary, such as more, less, how many in all, fewer, add, and take away. The number of math-related activities a child engages in at home is related to parents' use of mathematical language, both shown to be predictors of children's early math skills (Gürgah Ogul & Aktas Arnas, 2020). Applying this language to everyday activities like counting objects, looking at shapes, and talking about sizes can help children develop this foundational skillset. Shoring up these math competencies and providing the opportunity for exposure ahead of kindergarten allows additional bandwidth for children to navigate the multitude of cognitive, social, and emotional tasks awaiting them in this new academic setting.

Yet not all households prioritize developing an early math skillset or create the same type of early learning environment. Communities with diverse populations have additional layers of complexity influencing children's path to school readiness and math preparation. These layers can include factors such as the primary language spoken in the home, cultural beliefs about the role of parents in early academic learning, and the quality of the home numeracy environment to provide learning experiences that support children's early math development (Kung et al., 2020). In a meta-analysis of pre-kindergarteners, researchers found that monolingual children engaged in early math activities between 2-5 times per week at home, whereas dual language children engaged in those same activities much less frequently (between 1-3 times a month to once a week) (Kung et al., 2020). Hispanic immigrant families, dual language households in particular, may provide fewer opportunities for math learning in the home if they struggle with math or language themselves or feel that the teaching of academic skills is solely the responsibility of teachers or others in formal schooling environments (Galindo et al., 2019; Suárez-Orozco et al., 2008).

With the variability that exists across home learning environments, it becomes clear why school readiness gaps in basic math skills surface before children ever enter school. These gaps harden and widen over time, further reinforcing the importance of supporting the development of essential skills for all pre-kindergarten children, but most notably those lacking additional educational resources (Duncan & Magnuson, 2013; Maloney et al., 2015). While participation in early childhood education has increased for the Hispanic community today, Hispanic children continue to have the lowest levels of pre-kindergarten enrollment among all race/ethnicity groups in the United States (Hussar et al., 2020).

Early Mathematics as a Foundation for Later Math Skill Development

The foundational math knowledge that pre-kindergarten students ideally bring with them to kindergarten becomes the basis from which their skillset grows. Longitudinal studies tracking the development of early math skills from pre-kindergarten into elementary school found that the early acquisition of skills, including mathematical language and counting concepts, effectively prepares young learners for the more complicated math skills needed in later grades (Nelson & McMaster, 2019; Litkowski et al., 2020). In addition, studies have found that non-symbolic quantity and repeating pattern knowledge in pre-kindergarten predicted scores on high-stakes mathematics tests in grades four to six (Fyfe et al., 2019). Some research suggests a stronger connection between primary and later mathematical understanding compared to primary and later reading success (Terry, 2021), and this early numeracy preparation can influence a student's academic achievement up to high school (Claessens & Engel, 2013; Fyfe et al., 2019; Missall et al., 2012).

Most early math skills are categorized by researchers into number, relations, and operational domains (Nelson & McMaster, 2019). The skills within these domains have an important scaffolding effect. Critical early skills include counting, cardinality, measurement, and patterning, all of which are predictors of later math and academic achievement. These early skills encapsulate the ability to use numbers, operations, and counting-on strategies, which support the development of counting concepts, as well as skills in non-symbolic quantity (Claessens & Engel, 2013; Missall et al., 2012; Sedaghatjou & Campbell, 2017). Early relational skills allow understanding of the mental number line, knowledge of whole numbers, verbal number names, and their magnitudes (Nelson & McMaster, 2019). This early knowledge leads to more complex mathematical operations, such as addition and subtraction (Fyfe et al., 2019).

We see, however, that on day one of kindergarten, Hispanic dual language children may arrive with less than sufficient foundational math knowledge compared to their monolingual English-speaking peers. These differences create an early disparity in preparedness that widens with time and can result in continued math achievement gaps between the two groups (Kung et al., 2021; Yazejian et al., 2015). This disparity is important, given the predictive nature of an early math skillset and its documented benefits on later academic success.

Early Math as a Gateway to STEM

The experience with early math exposure, acquisition of skills, and ultimately feeling successful and enjoying the learning process all have the potential to drive young learners toward more STEM engagement and activities as they grow and develop. Recent research asserts that in addition to the benefits of early math on school readiness and math skill development, it can also seed interest in future STEM participation (Stinson, 2004; Gonzalez et al., 2020; Douglas & Atewell, 2017). Increasing the number of students interested in STEM activities, majors, and eventually careers, is undoubtedly a current and high priority for education practice and policy. But the groundwork should be laid early, and building an interest in STEM means building the skills from the beginning of a child's educational journey.

Nurturing the gateway to STEM for students as young as pre-kindergarten likely includes creating early access to curriculum that supports the development of emerging skills, providing content that helps children begin school on track for early success, and developing comprehensive programs that give parents and early education providers the necessary resources to encourage early STEM-related learning.

In the years beyond the gateway, studies show that Hispanic children (among other minority groups) are systematically underrepresented in science, technology, engineering, and mathematical domains, likely predicated by unequal exposure to the components of a solid STEM start (Musu-Gillete et al., 2017; "*Women, Minorities, and Persons with Disabilities in Science and Engineering*," 2021). Preparing children to be successful in STEM is a challenging process that is optimized when accessibility is prioritized from the start, a solid foundation of basic academic skills is targeted, and the diversity of young learners is acknowledged.

Given the underrepresentation and reported barriers to early math education, an alternative approach to kindergarten prep could have a strong and direct benefit on pre-kindergarten students, particularly Hispanic children, as they prepare for kindergarten (Turner et al., 2015).

Educational Technology for Early Learners

Educational technology offers an opportunity for underserved children to receive early education instruction regardless of diverse home learning environments or existing pre-kindergarten challenges. Technology has become a regular part of everyday life for many young learners and its use is increasing as a social and educational phenomenon (Laidlaw & Wong, 2016). Computer-based instruction is a beneficial tool in pre-kindergarten curriculum because it often incorporates immediate feedback, visual graphics, and adaptative lesson plans (Macaruso et al., 2006; Barron et al., 2011). Further, with computer-based instruction, teachers can strike a healthy balance between playful learning and structured lessons and provide individualized programming to meet each child's needs (Rogowsky et al., 2017). Compared to 10 years ago, pre-kindergarteners today have increased access to technology, like computers, tablets, and smartphones (Wartella et al., 2013), which allows for increased access to educational technology programs. In addition, internet access in educational settings increased from 81% to 97% from 2010 to 2018 (Hussar et al., 2020). As access to high-speed internet has expanded, there has been an abundance of educational software programs targeted to young learners, childcare centers, parents, and schools to support the development of children's early literacy and math skills (Wood et al., 2012).

An increasing number of studies suggest that children's later academic achievement can benefit from educational technology. Researchers found that use of computer technology had a positive effect on mathematics achievement in kindergarten through twelfth grade (Cheung & Slavin, 2013; Ran et al., 2020). Similarly, there was a positive relationship between exposure to educational technology curriculum during pre-kindergarten and school readiness. These benefits were further enhanced by children's additional computer experience at home (Li et al., 2006).

There is a demonstrated need for high-quality educational technology research, especially in early childhood education, as the number of educational software programs rapidly increases (Daugherty et al., 2014). However, researchers note that evaluative studies either do not exist prior to the software's release or there are methodological shortfalls that fail to meet the appropriate standards (Grant et al., 2012; Murphy et al., 2002; Cheung & Slavin, 2011). Moreover, although there are numerous educational software programs to help children prepare for school, there is a lack of research on the impact of computer interventions on different subgroups of students, including dual language learners.

Waterford's Upstart Program

Waterford's Upstart computer-based program has the potential to offer a quality educational curriculum to all young children but particularly to those in need of the earliest educational support. These children stand to benefit the most from targeted interventions focused on developing literacy, math, and social-emotional skills, all of which are critical for preparing children for kindergarten and setting them up for future long-term success. Given the need for more rigorous research and the potential benefits of computer-based programs for those with the most need, the Evaluation and Training Institute (ETI) partnered with the Waterford Research Institute to study the effects of the Upstart program on the early math skill development of pre-kindergarteners living in Nevada. **Appendix B** presents the Upstart program logic model that guided the current research.

The principal component of Upstart is an in-home computer-based school readiness software program that provides pre-kindergarteners with reading, math and science, and social-emotional learning curriculum. The program prepares 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 school readiness software is to use the program for 15 minutes a day, 5 days a week.

The Upstart math program is designed to use research-based best practices for early math instruction through the teaching of over 130 objectives, based on a review of standards from the National Council of Teachers of Mathematics, state and local standards, as well as current math texts ("Waterford Early Learning," 2011). These standards cover the domains of number & operations, operations & algebraic thinking, measurement & data, and geometry. The domain-specific mathematics skills are emphasized in activities like a daily number song, a math warm-up, a calendar activity, a skill for the day, a number lesson, and a session of play and practice ("Waterford Early Learning," 2011). The Upstart math curriculum is designed using conceptual math and basic cognitive skills. Conceptual math helps students explore the "meaning of operations, calculators, mental computation, estimation, and thinking strategies." At the same time, basic skills like fact retrieval and drill and practice commit problem-solving strategies to memory ("Waterford Early Learning," 2011). These two philosophies work in tandem to introduce "learned mathematical concepts into real-world situations." ("Waterford Early Learning," 2011). **Table 1** showcases the math domains and skills taught by Upstart math at the first level[1] of the curriculum: number & operations, operations & algebraic thinking, measurement & data, and geometry.

Table 1. Upstart Math Program Domains and Skills

Upstart Math Domains	Level 1 Math Skill
Numbers & Operations Teaches number recognition, place value, counting, and arithmetic computation.	• Recognize, order, and write numbers 0 through 20 • Order, count, and sequence numbers to 100 by ones and tens • Use strategies to compare group size (more than, less than, or equal to)
Operations & Algebraic Thinking Teaches arithmetic computation.	• Use objects, drawing, etc., to represent addition and subtraction • Add and subtract within 10, including solving word problems • Fluently add and subtract within 5 • Introduce place value of 2-digit numbers
Measurement & Data Develops a foundational understanding of measurement, time, and money. Prepares students to analyze data.	• Compare, classify, and describe measurable attributes of objects • Use digital and analog clocks to tell time to the hour • Identify coins and their value
Geometry Teaches properties of shapes, positioning, and the identification of parts of regions or groups.	• Identify basic shapes regardless of their orientation and environment • Create composite shapes • Learn about shape positioning • Understand similarities and differences in 2- and 3-dimensional shapes

[1] Level One is the beginning point of the curriculum, where the pre-kindergarten child is introduced to skills designed to teach the child mathematics. 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.

Research Focus

The current study set out to address several intersecting areas of inquiry within early math skill development. We looked at the effectiveness of bringing a high-quality and accessible computer-based program into the homes of young students as an opportunity to engage in a kindergarten prep program. We studied how the pre-kindergarten school readiness program impacted the early math skills of rising kindergarteners and how well the impacts were maintained a year later. And finally, we explored the impacts of the program on a population of children who were learning more than one language at home. The questions and methodology that guided our research are presented below.

Methods

The current Upstart study in Nevada had several main objectives. The primary focus was on the program's impact on early math skill development at two different points in time; at the end of the pre-kindergarten year and at the end of the kindergarten year. Given the population in the state of Nevada, we also explored how the Upstart program impacted both dual language and monolinguistic learners.

Research Questions and Hypotheses

We designed a randomized control trial (RCT) experiment to test our primary research questions, which included the following two confirmatory contrasts between treatment and control students. Throughout this paper, *treatment* refers to those in the math program, and *control* refers to those in the reading program.

1. Did pre-kindergarten children randomly assigned to receive the Upstart math software program during their pre-k year have higher scores than their

counterparts assigned to the Upstart reading program on measures of emerging math concepts and applications?

Pre-k hypothesis: If Upstart math influenced early math skills, then children in Upstart math should perform significantly better than the comparison group on measures of early math development at the completion of the program year.

2. Did children who were randomly assigned during their pre-k year, to receive the Upstart math software program have higher scores than their counterparts assigned to the Upstart reading program on measures of math concepts and applications at the end of kindergarten?

   Kinder hypothesis: If the program had enduring effects, we would expect treatment children's end of year kindergarten math scores to exceed those of the control students.

We also tested the following exploratory research question:

3. Did the Upstart math program differentially impact students who are dual language learners (i.e., Spanish home language) on measures of emerging math skills compared to their monolinguistic counterparts (i.e., English as their home language)?

Participants

The Upstart program served families in Nevada living in or near the major cities of Las Vegas, North Las Vegas, Henderson, and Reno. The program was offered to age-eligible English-speaking children and Dual Language Learners (DLL)[2]. Waterford asked parents three questions to determine their DLL eligibility. Parents were asked to state their primary language

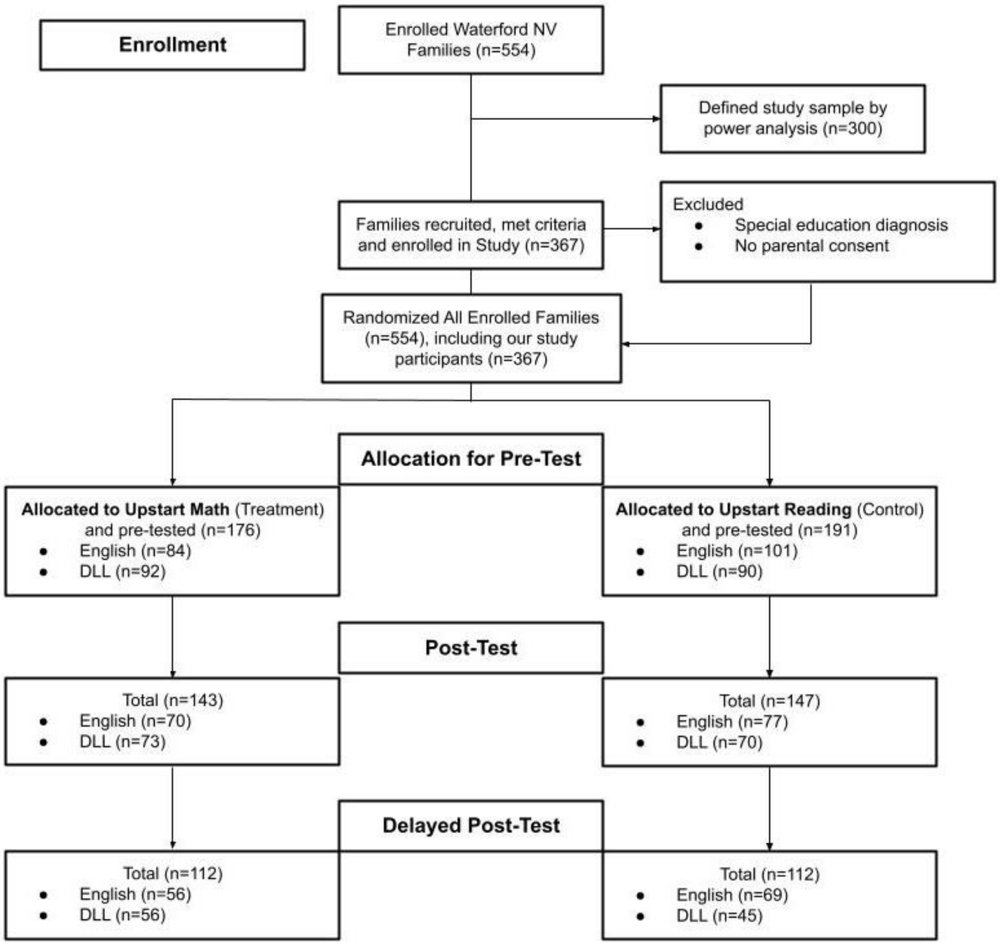
[2] Age-eligible children are children entering kindergarten in the fall of 2021.

and the primary and secondary language of their enrolled child. If parents listed “Spanish” as a response to one or more of the three language questions, then their child was categorized as a DLL participant. ETI recruited research participants through a screening and eligibility[3] process to evaluate the effectiveness of the program. ETI administered assessments to children before and after the Upstart program and then again a year later when they finished kindergarten.

Research participants were 367 pre-kindergarteners randomly selected out of 554 families enrolled in the Upstart program (the research sample was roughly 66% of the total program group size at the start of testing). Pre-kindergarteners were randomly assigned to the Upstart math program (Treatment sample; N =176; English = 84 and DLL = 92) and to Upstart reading (Control sample; N = 191; English = 101 and DLL = 90). Random assignment was done after families completed baseline assessments. Ideally, all children who were pre-tested would have been post-tested. However, as in most studies that rely on repeated measures, that ideal is rarely attained. **Figure 1** illustrates the participant flow from program enrollment before the pre-kindergarten year through the delayed post-test assessment at the end of kindergarten.

[3] Program families were excluded from the evaluation if their child was not proficient in English or had a diagnosed learning disability.

Figure 1. Participant Flowchart



Measures

The Kaufman Test of Educational Achievement Third Edition (KTEA-3) was administered to measure the effectiveness of the Upstart math intervention on emerging math skills. The KTEA-3 is a widely used measure of student achievement and measures academic skills in reading, math, written language, and oral language (Kaufman & Kaufman, 2014). The instrument has shown good psychometric properties, with the overall reliability ranging from

0.87 to 0.95. The KTEA-3 includes age-appropriate early math scales for pre-kindergarten and kindergarten students.

Children's *Math Concepts and Applications* were measured with an 87-item scale ranging from 0-87 that included basic concepts including (but not limited to) number identification, shape identification, varying quantities (more/less), and sequencing.

Design and Procedures

An intent-to-treat randomized control trial design was used and included three observations across a two-year period (diagrammed in **Figure 2**). Early math pre-tests were conducted prior to participants' random assignment into conditions to establish achievement baseline levels and then followed by two post-test periods, one immediate and one delayed.

Figure 2. The Evaluation Design of the Pre-Kindergarten and Kindergarten Study

<table>
<tr><th colspan="2">Summer 2020</th><th></th><th>Summer 2021</th><th></th><th>Spring 2022</th></tr>
<tr><td rowspan="2">Pre-Test</td><td rowspan="2">Random Assignment</td><td>Upstart Math Treatment</td><td rowspan="2">Post-Test</td><td rowspan="2">Kindergarten</td><td rowspan="2">Delayed Post-Test</td></tr>
<tr><td>Upstart Reading Control</td></tr>
</table>

Children were recruited to participate in the research study in the summer of 2020. Children in both conditions (Math and Reading) completed their respective programs over an eight-month period, and post-program assessments were conducted after the Upstart program was completed in the summer of 2021. The delayed post-test assessments were conducted in the spring of 2022 when the children were completing their kindergarten year.

Assessments were individually administered to children by trained test administrators (TAs). Due to social distancing, closures, and travel restrictions as a result of the pandemic, all test administration was virtual using an online platform, and developed to address the health and safety regulations (see **Appendix A** for more details). 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 the treatment and control groups. In the weeks leading up to the beginning of each data collection period, ETI recruited and trained the TAs in virtually administering the KTEA-3 assessment in tandem with launching study participation invitations and scheduling families for assessments. During the first week of data collection, we conducted observations of each TA using a structured protocol to ensure the assessments were conducted with fidelity. This process was again repeated halfway through data collection. Additionally, a data quality procedure was conducted at three points–beginning, middle, and end–of each data collection period. This procedure consisted of comparing the mean scores of all TAs utilizing bivariate statistical analyses. These observations and data quality procedures were conducted to ensure all staff were implementing the testing protocol consistently and accurately. ETI provided Amazon gift cards as incentives to participating families, which were electronically distributed on a weekly basis until the end of each data collection period.

Data Analytic Approach

Several analytic steps were taken to determine the extent to which a math intervention among preschoolers impacted early numeracy skill development. Before any outcome analyses were conducted, we examined children's baseline characteristics to confirm that treatment and control groups were equivalent on pre-test achievement scores and demographic factors at the start of pre-kindergarten. Hypothetically, if significant differences are observed at the outcome, it is critical that they cannot be attributed to differences that existed from the start. We found no statistically significant differences at baseline between our treatment and control samples.

Next, we used ordinary least squares (OLS) multiple regression models to examine the impact of the treatment on math achievement Growth Scale Value scores (GSVs). The KTEA-3 provides GSVs as a measure of change over time, or growth, to describe an examinee's absolute level of performance as opposed to their relative performance provided by the age-adjusted standardized scores. Comparing GSVs across pre-test, post-test, and delayed post-test provided information about the magnitude and direction of growth over time among Upstart participants. Predictor variables used in the regression models included treatment status, baseline achievement scores at pre-test, and a dichotomous variable for dual language learners (DLL). We studied the overall impact of the intervention by treatment and control condition, as well as the interaction between language status and treatment condition. Hedges' g effect sizes were calculated to illustrate the magnitude of the difference between the two conditions and compare the strength of the impacts across measures.

The predicted mean scores and effect sizes from the regression models are presented by observation time period (pre-kindergarten post-test and kindergarten delayed post-test).

Statistical Analysis

We defined the following variables for each pre-kindergarten child in multiple linear regressions to estimate the impact of Upstart math on our outcome variables of interest: Y_{ij} is the child's score on post-test measures of math concepts and applications; Treatment (T_{ij}) is an indicator for whether the child received the intervention (Treatment = 1 if the student was randomly assigned to the Upstart treatment intervention, Treatment = 0 if the child was randomly assigned to the Upstart control condition); $Y^{Pre}{}_{ij}$ is the child's score on pre-test measures (pre-test covariate); $Y^{DLL}{}_{ij}$ is an indicator of a child's dual language learner status (DLL = 1 if the child speaks Spanish in the home and is also learning English, DLL=0 if the child is monolinguistic). One possible linear regression model that uses these variables is the following:

$$\mathrm{Y_{ij}} = \beta_0 + \beta_1(\mathrm{T_{ij}}) + \beta_2(\mathrm{Y^{Pre}}_{\mathrm{ij}}) + \beta_3(\mathrm{Y^{DLL}}_{\mathrm{ij}}) + \varepsilon_{\mathrm{ij}}$$

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

- β_0 is the intercept;
- β_1 is the expected increase in the post-test score for pre-kindergarteners who participated in the Upstart math intervention relative to students who did not receive the intervention;
- β_2 is the effect of pre-test data; and,
- β_3 is the effect of dual language learner (DLL) status.

We explored covariate interactions between Treatment (β_1) and DLL (β_3) to determine if treatment effects were significantly different for DLL students.

Results

Baseline Equivalence

Baseline equivalence was established between the treatment and control groups on pre-test measures of math achievement using independent samples *t*-tests. Mean differences are presented, along with *t*-values and significance levels.

Table 2 presents pre-test mean scores on math concepts and applications. Initial results from *t*-tests indicate that there were no significant pre-program differences between children assigned to treatment and control conditions on the math subscale, indicating comparable levels of early math skills between the two experimental groups prior to beginning the Upstart program.

Table 2. Baseline Equivalence of Treatment-Control Groups

Subscale	*N*	Mean	*SD*	*t*-value
Math Concepts and Applications				
Treatment	176	387.32	22.93	0.4408
Control	191	388.38	22.80	
Note. *p<0.05				

Table 3 presents the baseline equivalence of participant characteristics using Fisher's Exact test. There were no significant differences between the treatment and control conditions for any participant demographic characteristics.

Table 3. Baseline Equivalence of Treatment-Control Groups by Participant Characteristic

	N	Percent	*p-value*
Female			
Treatment	91	51.70	1.000
Control	99	51.83	
White			
Treatment	57	32.39	0.427
Control	54	28.27	
DLL Status			
Treatment	92	52.27	0.348
Control	90	47.12	
Under 200% Poverty			
Treatment	63	44.68	0.486
Control	65	40.62	

Note. $^*p<0.05$

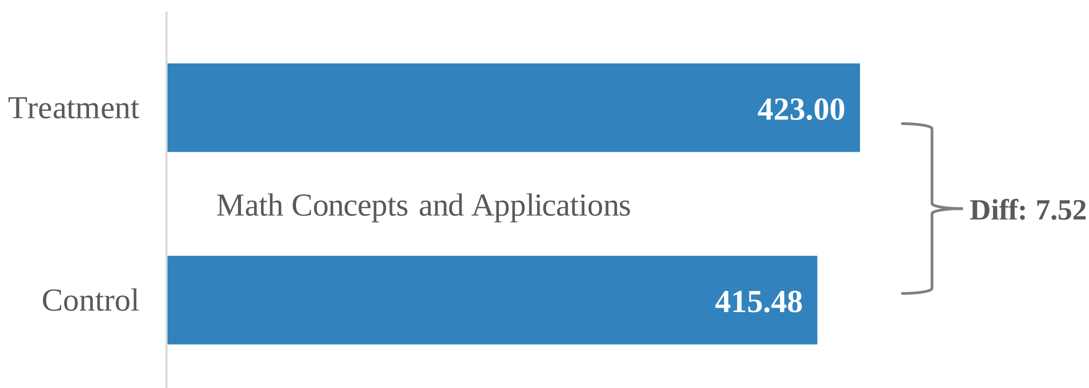
Program Impacts on Outcome Variables

Pre-Kindergarten. It was hypothesized that treatment students, who received Upstart math during their pre-kindergarten year, would score higher on a measure of early math achievement than students in the control condition who received Upstart reading. The regression analysis displayed in **Table 4** shows that Upstart math had a significant influence on children's early math skill development, with treatment students outperforming the control group on math concepts and applications ($\beta=0.182$, $p = 0.003$). **Figure 3** illustrates the seven-point difference between the treatment and control predicted mean scores on the post-test assessment.

Table 4. Pre-Kindergarten Regression Analysis of Predictors of Math (N=290)

Variable	*B*	*SE B*	*β*
(Constant)	188.303	16.153	
Treatment	7.647	2.559	.182**
Pre-Test	.587	.041	.644**
DLL	-2.474	2.609	-.059
Treatment*DLL	-.265	3.645	-.005
R^2		0.466	
F		62.06**	
Note. *p<0.05; ** p<0.01			

Figure 3. Predicted Treatment and Control Math Post-Test Mean Scores



However, there were no significant interaction effects between the treatment condition and DLL status. That is, children living in dual language households were impacted by the intervention similarly to their monolinguistic peers (β = -0.005, p = 0.942).

Kindergarten. To determine if the pre-kindergarten intervention had enduring effects lasting through the kindergarten year, students were tracked and tested again in the spring of their kinder year. It was hypothesized that treatment students, who received Upstart math during their pre-kindergarten year, would score higher at the end of kindergarten on a measure of math than students in the control condition who received Upstart reading. The regression analyses displayed in **Table 5** show that children in the treatment condition continued to outperform their control group peers on math concepts and applications at the end of kindergarten, nearly one year following the intervention (β = 0.151, p = 0.028).

Table 5. Kindergarten Regression Analysis of Predictors of Math (N=226)

Variable	*B*	*SE B*	β
(Constant)	209.067	19.376	
Treatment	6.113	2.766	.151*
Pre-Test	.606	.049	.639**
DLL	-1.696	2.967	-.042
Treatment*DLL	-.981	4.138	-.021
R^2		0.433	
F		42.10**	

Note. *p<0.05; ** p<0.01

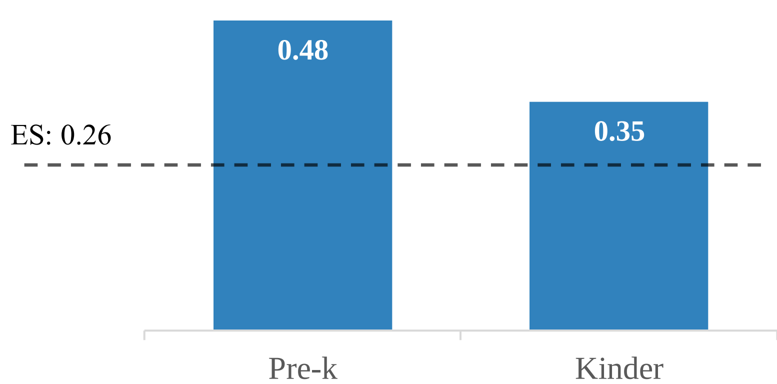
Figure 4 shows a five-point difference was maintained between the treatment and control predicted mean scores at the end of kindergarten.

Figure 4. Predicted Treatment and Control Math Delayed Post-Test Mean Scores

Again, we found no significant differences in how DLL and non-DLL treatment students were influenced by the intervention a year later (β = -0.021, p = 0.813).

Program Effect Sizes. The effect size estimates for both points in time are presented in **Figure 5** and show the magnitude of the average performance differences in standard deviation units between the treatment group and the control group. 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 for measures of math concepts and applications were derived from the linear regression analysis and controlled for prior knowledge and DLL status. The current study used an effect size threshold of 0.26 found in similar educational interventions with similar targets. The Upstart math program produced substantive impacts for early math skills among the treatment group of children after the pre-kindergarten year (Hedges' g = 0.48) and maintained the benefits through the kindergarten year (Hedges' g = 0.35).

Figure 5. Pre-Kindergarten and Kinder Year Effect Size Estimates based on Growth-Scale Values



We additionally examined learning growth over time between the treatment and control children. **Figure 6** shows the math GSVs across three different points in time (pre-test, post-test, and delayed post-test). Both groups of children started their pre-kindergarten year similarly, yet at the end of the program year, those participating in the math intervention demonstrated a greater degree of math skill acquisition relative to the reading comparison group. This elevated growth rate continued through the kindergarten year, with math program participants outperforming their reading program peers.

Figure 6. Predicted Math Achievement

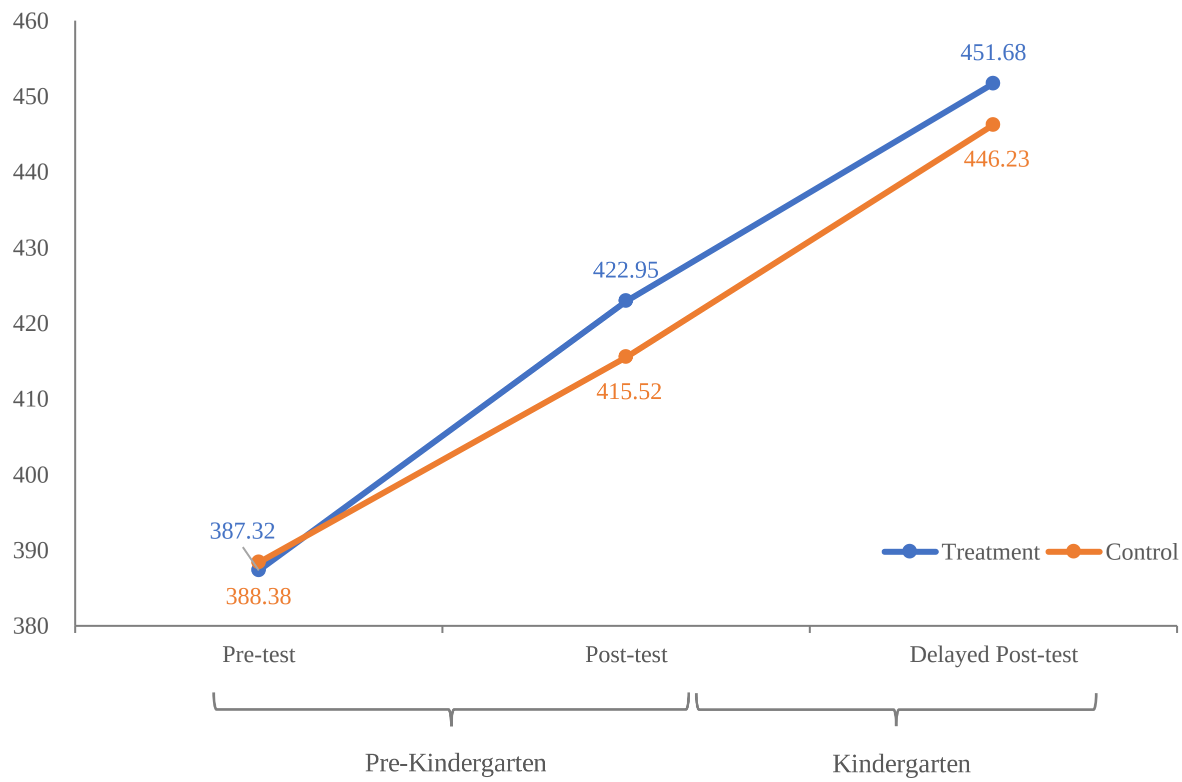
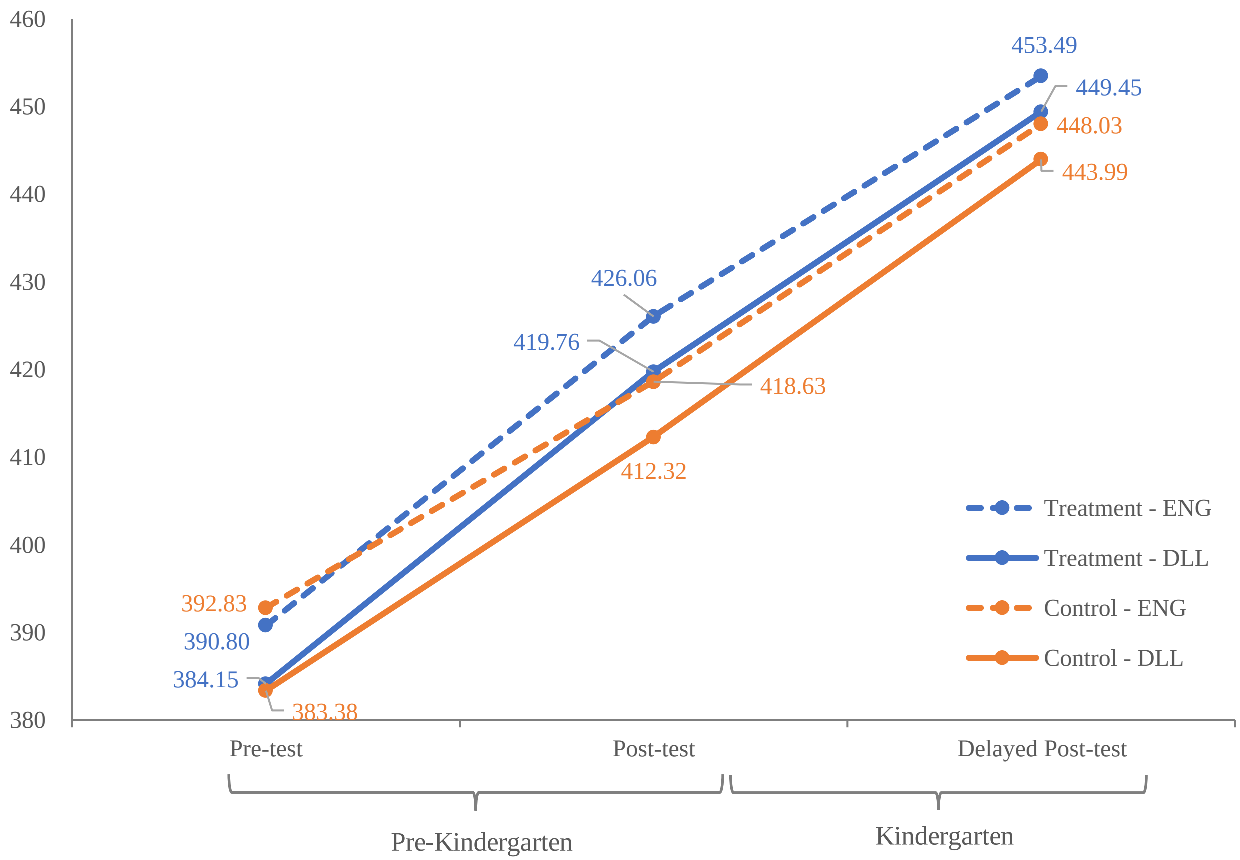


Figure 7 depicts the growth over time by treatment condition and language. Overall, monolinguistic students assigned to either reading or math tended to outperform their DLL counterparts assigned to the same intervention at the end of pre-kindergarten and kindergarten.

Interestingly, DLL children participating in the math intervention score similarly in math to their English-only peers who participated in the reading program.

Figure 7. Predicted Means of the MCA Growth Scale Value by Treatment Condition and Language Group



It is possible that participating in Upstart math assisted DLLs in shoring up their numeracy skills to levels comparable to their non-DLL peers.

Summary and Discussion

The current study measured the extent to which the Nevada Upstart math program improved children's school readiness in early math concepts and applications. Children who participated in the math program during their pre-kindergarten year outperformed their comparison counterparts on measures of early math achievement at the end of the program. We also found evidence that math skills gained during the pre-kindergarten year were maintained a year later. We noted similar program impacts for both monolinguistic and DLL students, suggesting that the intervention was equally beneficial within these linguistically diverse households. These findings are promising, given DLL students' mixed results in English-only math interventions (Choi et al., 2018; Kung et al., 2020).

Early math skills have gained traction as a critical component of school readiness and an important predictor of later academic achievement (Hardy & Hemmeter, 2019; Jordan et al., 2010). Establishing these skills prior to school entry prepares young learners, particularly underrepresented students, for a solid foundation in a skillset shown to support continued school success. This study provided evidence that the Upstart math program effectively impacted a numeracy skill foundation and supported overall school readiness for Nevada children. The gains demonstrated by the participating students have the potential to persist and build into the elementary years and beyond, as shown in other longitudinal studies that report similar findings (Claessens & Engel, 2013; Fyfe et al., 2019; Missall et al., 2012).

Importantly, the current study highlights the potential of a technology-based intervention to serve as the vehicle for acquiring these early skills. The Upstart math program served as an accessible and effective resource for establishing early math skills prior to kindergarten, one that may assist in minimizing the achievement gap seen in early mathematics for certain students.

Home-based interventions aimed at developing this essential footing should be encouraged, particularly among underserved students and those who need access to a school readiness program. The in-home computer-based delivery method removed barriers to access due to geographic or socio-economic limitations while also providing an individualized curriculum to meet each child's needs. Given a growing national focus on increasing interest and engagement in STEM domains, the Upstart math program is well positioned to serve as an early contributor to this foundation.

The educational landscape in Nevada is diverse, with 43% of Nevada children aged 0-5 classified as dual language learners (Giang & Park, 2022). Meeting the early childhood education needs of Nevada's youngest students is an essential task for early childhood education policymakers and professionals within the state. The positive impact that this educational technology had on both DLL and non-DLL students is encouraging, given the reality of Nevada's linguistic, socio-economic, and cultural characteristics. The significant findings at the end of the pre-kindergarten and kindergarten year elicit several additional questions. What impact might this same program have among populations of children that are historically disadvantaged in math achievement and/or underrepresented in STEM subjects overall? How may this educational technology change the game for those without access to traditional school readiness programs? The answers could inform future programming efforts and recruitment strategies for Upstart (and others) and offer ways to support math achievement and school readiness for the young students across the country who need it the most.

Limitations

Sample Size. The current study utilized a relatively small sample of students focused on a unique population in Nevada, namely Hispanic students learning more than one language at home. We also studied their monolinguistic peers, however, there are many more pre-kindergarten subgroups across the country that could benefit from an in-home technology-based math intervention. Expanding the characteristics of the children under study will help generalize the findings across a much wider base of pre-kindergarten students.

Beyond the Short-Term. Our work tracked students through their kindergarten year and found that gains made in pre-kindergarten mathematics were maintained a year later. While this finding has important implications for the benefit of a pre-kindergarten intervention, we acknowledge that this study was not designed to measure the impact past this one-year milestone. We have learned from other research that early numeracy skills continue to build and contribute to a student's understanding and increased achievement over multiple years. In a sense, shoring up these math skills from the beginning actively lays the groundwork for the next more complex phase of skill development. The current lens was more near-term focused; however, we recognize the importance of understanding how the impacts play out over the long term.

Pandemic Year Influences. Research conducted among families and students over the last several years were inevitably impacted in some way by the events of the pandemic. The children who participated in this study were enrolled in the Upstart program during the 2020-2021 academic year. Schools in Nevada maintained remote learning until March of 2021, adding to the family-life upheaval experienced during the implementation of this home-based intervention. The timeframe of this study marks a period when families were adjusting and adapting to unprecedented modifications in their lives, schools, and workplaces across the state. Certain families may have been out of work, as well as other major social, economic, and psychological disruptions impacting their ability to provide an optimal home learning environment. Given the magnitude of this historic event, we acknowledge that we were unable to control for all possible scenarios in our analysis.

Future Research

Expanding the Sample and the Window. To broaden our understanding of how the Upstart math program works for a broad range of students, we recommend that future research include a larger sample of students from different geographic regions, different racial/ethnic backgrounds, varying socio-economic groups, and diverse learning needs. Future research is critical to further understand how the impacts of Upstart math during pre-kindergarten can be maximized for all students and how the program can continue to effectively support school readiness. In addition to expanding the types of children served, future research with Upstart math (and other early math interventions) should continue to follow the potential long-term achievement outcomes stimulated by an early foundational skillset. Future work could explore the lasting impacts of the Upstart math intervention on math outcomes as students continue their academic journey. For those most interested in improving STEM education, it would be valuable to understand the extent to which the benefits of a pre-kindergarten math readiness program are fostered over time, increasing engagement, confidence, and the desire to learn more.

Pre-kindergarten Home Numeracy Environment. The home numeracy environment, as asserted by recent literature, is influential in developing a foundational skillset for all young students, but even more so for certain types of students (Kung et al., 2020; Galindo et al., 2019; López & Donovan, 2009). Our study did not target the existing home numeracy landscape or the practices and strategies that may have already been in place. More research is needed to fully understand how home-based math interventions such as Upstart are interacting with the home numeracy environment and impacting the math skill development of pre-kindergarten children. Some pre-kindergarten households (and possibly even the majority) may be prioritizing reading, language, and literacy skills in the home. An early math intervention, therefore, may bridge a gap and offer instruction in an area that the home learning environment is not explicitly addressing. Future work could explore the best way to leverage home-based math interventions (delivered through educational tech) as an essential component of home practices for kindergarten readiness and develop a better understanding of how the two can be leveraged to maximize benefits.

Connecting the Dots

The U.S. Department of Education has been clear about the shifting priorities around STEM education and the importance of removing long-standing barriers that impede a student's ability to do well in STEM-related fields. The goal is "ensure all students from PreK to higher education excel in rigorous, relevant, and joyful STEM learning" ("*U.S. Department of Education launches new initiative*," 2022). There are initiatives in place and significant federal funds earmarked for this purpose. This educational endeavor begins with the youngest students, as acknowledged and supported by the federal government. We know that developing an early numeracy skillset is a critical part of school readiness. These basic mathematical abilities provide a foundation from which more advanced skills develop and benefit children into elementary school and beyond. We also know that interventions can be successfully delivered through educational technology in the homes of pre-kindergarten students who may otherwise not have access to school readiness programs. This is undoubtedly an exciting time to study a program for which its very content is front and center within the highest educational agencies; it unites high-quality innovation and accessibility and has growing evidence of its effectiveness on early academic outcomes.

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APPENDIX A. Virtual Assessment Procedures

The format of the school readiness assessments changed as a result of safety measures instituted to prevent the spread of the novel coronavirus (SARS-CoV-2). In this Appendix we describe the testing procedures implemented for virtual assessments for Cohort 2 for all data collection periods starting summer 2020. Our approach focused on maintaining the integrity of the assessments and keep the procedures similar despite the change in testing format.

Virtual Testing. ETI modified data collection procedures during the summer of 2020 to complete all testing online. All measures used to collect parent and student data were moved to online systems that were remotely managed by ETI staff. A link to complete the informed consent form, parent survey and the SSIS Rating Scales survey were emailed to parents for completion prior to their child's online assessment. Items from the SSIS SEL Scales were combined with SSIS Rating Scale items in the summer of 2021 to create one scale measuring social-emotional learning and development among students. For students, a combination of video conferencing, desktop sharing and computer co-browsing software was used to create an online interactive testing platform that mimicked in-person testing using the KTEA-III. Test administrators had visual contact and audio capabilities with the student through video conferencing and the student could interact with the test stimuli through a custom co-browsing software application. These features allowed for an interactive "virtual KTEA-III" test, and the student could point to test stimuli using her/his computer mouse.

Test administrators assisted parents with the technical setup prior to the child assessment to ensure the appropriate technology was present and functioning properly (called a "tech check"). Once the tech check was completed, the test administrator could then conduct the assessment with the child. Gift cards for completing the testing and the online forms were emailed to parents following completion of all parent forms and the virtual child assessment.

APPENDIX B. Upstart Program Logic Model

Key Components Inputs/Activities

Program Usage

<u>Usage requirements</u>
•5 times/week
•15 minutes each session
•9 months of total use

Educational Technology

<u>Provision of Technology</u>
- Distribute computers to all families
- Provide families in need with internet access
- Establish access to cloud-based software

Support

<u>Parent Support</u>
- Parent training session conducted by Waterford staff
- Parent Manager Portal software feature
- Social-emotional education training

<u>Curricular Support</u>
- Emails about curricular features of software program

<u>Motivational Support</u>
- Monitors program use and conduct motivational calls

Outcomes

Short-Term Outcomes

Increases in skills associated with early math
- Numbers and counting
- Numeracy and number relationships
- Operations and algebraic thinking
- Measurement and data
- Geometry and spatial sense

Long-Term Outcomes

- Increased rates of proficiency on standardized academic tests of Mathematics
- Increased rates of grade promotion
- Fewer students with the need for math intervention resources
- Increased engagement and motivation to engage in numeracy activities

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