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Impact Evaluation of Imagine Math Facts in a Southwestern Public School District

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Introduction

For students to be considered proficient in mathematics, they need to develop an understanding of foundational mathematical concepts and be able to efficiently retrieve arithmetic facts (National Mathematics Advisory Panel [NMAP], 2008). Students who lack proficiency and fluidity with their math skills are more likely to experience mathematical deficiencies later in their education and are less likely to develop the understanding needed for subsequent mathematical concepts (Kilpatrick et al., 2001; NMAP, 2008; Rivera & Bryant, 1992; Shapiro, 2010; Woodward, 2006). Research has indicated the importance of achieving math fact fluency particularly as it pertains to later mathematics achievement (Geary, 2011). Specifically, this early math fact fluency is critical for success in algebra and geometry (Nelson et al., 2016; Steel & Funnell, 2001).

Digital learning tools are a productive way for students to develop automaticity and fluency with their mathematics skills (Lindeman, 2019). Imagine Math Facts by Imagine Learning is a digital program that helps students gain fluency and automaticity in addition, subtraction, multiplication, and division in an engaging 3D game environment. The program can be implemented in class or as homework and provides students with a foundation for higher-order thinking to build pre-algebra readiness. As such, students who utilize Imagine Math Facts as intended are expected to improve and accelerate their mathematics skills proficiency.

In partnership with a southwestern school district, Imagine Learning conducted a study designed to evaluate the efficacy of Imagine Math Facts. The primary research question was: how does use of Imagine Math Facts impact elementary students' mathematics achievement? Reported study results demonstrate that the program positively impacted students' mathematics proficiency by comparing the performance of Imagine Math Facts students to a statistically similar group of students who did not use the Imagine Math Facts program.

Methods

RESEARCH DESIGN

Imagine Learning partnered with a public school district in the southwestern United States to evaluate how Imagine Math Facts impacted the math proficiency of its students. During the 2022–2023 school year, Imagine Math Facts was made available to students in Grade 1 through Grade 5 and was used at teachers' discretion. In many cases, it was implemented in the classroom or at home if a teacher deemed it valuable to support the learning of an individual student outside of the classroom.

This study was conducted retrospectively using data from the 2022–2023 school year to evaluate the difference in mathematics achievement between treatment and control students. The treatment group was comprised of all students who logged any usage in the Imagine Math Facts program during the 2022–2023 school year, while the control group included all students

who did not. This study is a quasi-experimental design as assignment to the treatment and control groups was not random. Statistical procedures were used to ensure baseline equivalence of the treatment and control samples.

MEASURES

Multiple data sources were compiled to describe students, their performance, and their work in Imagine Math Facts. Student mathematics proficiency outcomes were determined using a standardized assessment. Student demographic data were collected to provide additional information on student characteristics that may impact measures of learning outcomes. Data from the Imagine Math Facts program were incorporated to evaluate student engagement in Imagine Math Facts. These data sources are reviewed in more detail below.

Mathematics Proficiency. Students' mathematics proficiency was determined using the Renaissance Star (Ren Star) mathematics assessment for students in Grades 1 through 5. The average number of days between the Fall 2022 and Spring 2023 assessments was 245 (242 days for students in the control group and 247 days for students in the treatment group). Unified Scale scores from the Fall 2023 administration of the Ren Star math assessment were used to establish baseline equivalence between study groups, and Spring 2023 Unified Scale scores were used to estimate the effect of using Imagine Math Facts on mathematics proficiency. The Ren Star Unified Scale score is a composite score on a Rasch score scale.

Student Demographics. Information on individual student demographic characteristics was also collected. In particular, student grade level, ethnicity, gender, and special education status were provided by the district and used to control for other factors that may impact student learning.

Imagine Math Facts Usage. Program usage data was obtained to determine students' engagement and progress in Imagine Math Facts. These data included the total minutes students spent in the program, the number of math facts correctly answered, and whether each operation (addition, subtraction, multiplication, division) was completed in the program.

ANALYTICAL SAMPLE

A total of 3,308 treatment students who used Imagine Math Facts and 2,791 control students who did not use Imagine Math Facts were initially identified. To ensure that the baseline characteristics of treatment and control students used in analyses were comparable, 1:1 nearest neighbor propensity score matching without replacement was used to create a statistically equivalent analytical sample.[1] Control students were matched to treatment students based on their Fall 2022 Ren Star Unified Scale score, gender, ethnicity, and special education status. This matching process was completed on each grade individually before combining the matched grade-level samples to create the two analytical samples: one with students in early elementary grades (Grades 1 and 2) and a second with students in upper elementary grades (Grades 3

[1] Propensity score matching was executed using the matchit function in R's MatchIt package with the caliper set to .05 and exact matching on grade, ethnicity, gender, and special education status.

through 5). Since some results might have been obscured were analyses conducted across all grade levels together, outcomes were evaluated based on grade clusters and then on individual grades. The resulting analytical samples included a total of 2,261 users of Imagine Math Facts and 2,261 non-users. **Table 1** and **Table 2** below describe the characteristics of the early elementary and upper elementary analytical samples.

Table 1. *Student Characteristics of the Early Elementary Analytical Sample*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	951	951		
Average (*SD*) Fall 2022 Ren Star Unified Scale Score	822.31 (62.81)	823.79 (58.73)	.597	0.024
Grade			>.999	<0.001
Grade 1	504	504		
Grade 2	447	447		
Gender			>.999	<0.001
Female	484	484		
Male	467	467		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	509	509		
Yes	442	442		
Special Education			>.999	<0.001
No	868	868		
Yes	83	83		

Table 2. *Student Characteristics of the Upper Elementary Analytical Sample*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	1,310	1,310		
Average (*SD*) Fall 2022 Ren Star Unified Scale Score	982.60 (63.33)	980.77 (63.58)	.460	0.029
Grade				
Grade 3	408	408		
Grade 4	*457*	*457*		
Grade 5	*445*	*445*		
Gender			>.999	<0.001
Female	648	648		
Male	662	662		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	739	739		
Yes	571	571		
Special Education			>.999	<0.001
No	1,184	1,184		
Yes	126	126		

ANALYTICAL APPROACH

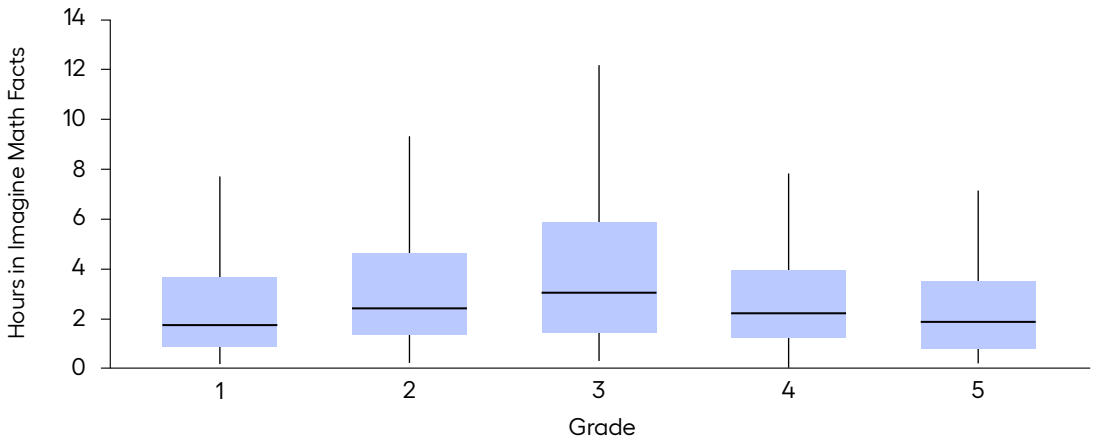
Multiple linear regression was used to evaluate the differences in achievement between Imagine Math Facts users and non-users in each analytical sample, controlling for baseline achievement and demographic covariates. An indicator of whether a student was a control or treatment student was included in the regressions as the primary predictor variable. Using multiple linear regressions after propensity score matching ensured that any remaining differences in the underlying treatment and control samples were controlled for by the regression model, effectively isolating the impact of Imagine Math Facts.

Results

IMAGINE MATH FACTS USAGE

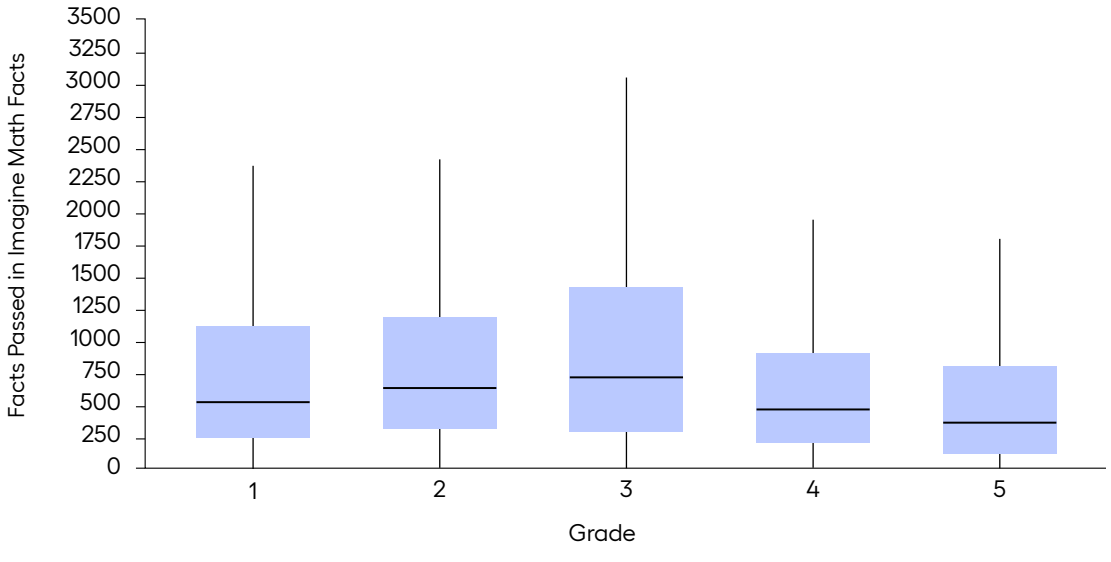
Treatment students spent an average of 3.38 hours in Imagine Math Facts and passed an average of 848.67 math facts. Average time in Imagine Math Facts varied by grade level, with the highest average usage in Grade 3 and the lowest average usage in Grade 5. See **Figures 1** and **2** for a distribution of hours and facts lessons passed by grade.

Figure 1. *Distribution of Hours Spent in Imagine Math Facts by Grade*



Note: Outliers that fall above 1.5 times the interquartile range are not included in this figure to ensure readability. The global maximum hours spent in Imagine Math Facts is 36.21 hours.

Figure 2. *Distribution of Facts Passed in Imagine Math Facts by Grade*



Note: Outliers that fall above 1.5 times the interquartile range are not included in this figure to ensure readability. The global maximum number of facts passed in Imagine Math Facts is 9,510 facts.

Treatment students in early elementary grades correctly answered more addition facts than any other operation, whereas students in upper elementary grades correctly answered more multiplication facts than any other problem (see **Figure 3**). Once students have mastered the facts within an operation, as demonstrated by a passing score on a post-test, the operation is considered completed in the Imagine Math Facts platform. In all grades, addition is the most completed operation (see **Figure 4**).

Figure 3. *Percent of Correct Facts in Imagine Math Facts by Grade and Operation*

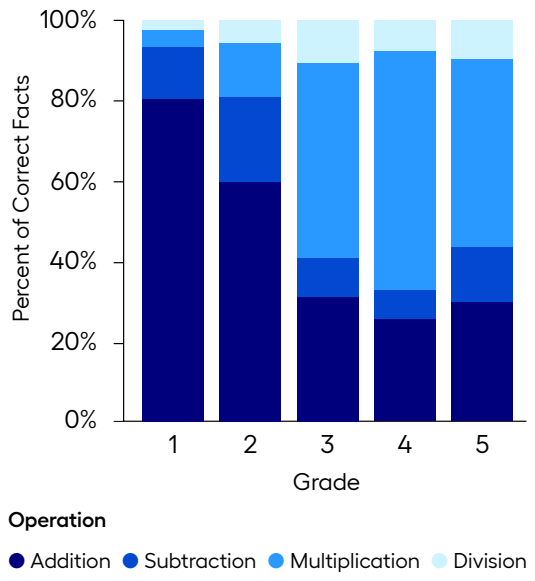
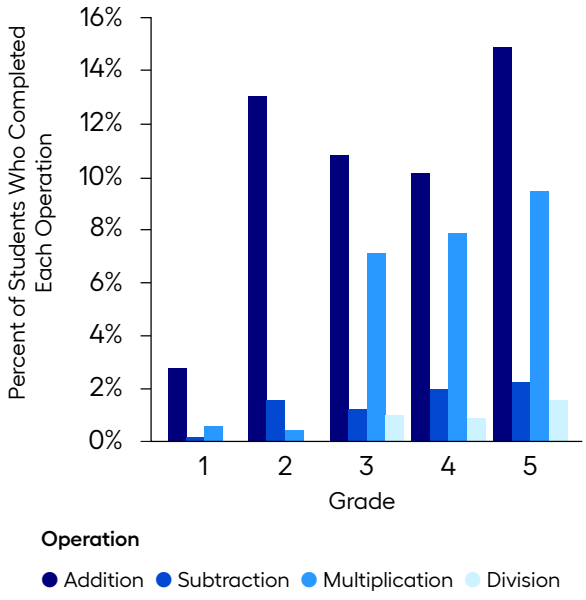


Figure 4. *Percent of Students Who Completed Each Operation by Grade*



PROGRAM IMPACT ON STUDENT ACHIEVEMENT

Use of Imagine Math Facts was found to generate a positive and statistically significant impact on students' mathematics proficiency for students in early elementary grades. Specifically, early elementary students who used Imagine Math Facts scored an average of 6.71 points higher on the Spring 2023 Ren Star mathematics assessment than otherwise similar non-user students, $B = 6.71$, $t(1895) = 3.879$, $p < .001$. Program usage and the other covariates in the model accounted for 65% of the variance found in Spring 2023 scores, $R^2 = .648$, $F(6,1895) = 582.3$, $p < .001$. The Hedges' g effect size of Imagine Math Facts program usage is .106.[2] **Table 3** summarizes the results of the multiple linear regression for students in early elementary grades. Use of Imagine Math Facts was found to generate a non-significant impact on students' mathematics proficiency for students in upper elementary grades. **Table 4** summarizes the results of the multiple linear regression for students in upper elementary grades.

[2] The effect size is calculated using Hedges' g computation following What Works Clearinghouse's Procedures and Standards Handbook, Version 5.0. The unadjusted standard deviations of the Spring 2023 scores can be found in **Appendix A**.

Table 3. *Overall Impact of Imagine Math Facts on Spring 2023 Ren Star Math Unified Scale Score in Early Elementary Grades*

Variables	Estimate	Standard Error	*p*-value
Intercept	253.15	15.02	<.001
Imagine Math Facts User Indicator	6.71	1.73	<.001
Grade-Level Indicator			
Grade 2	8.54	2.22	<.001
Fall 2022 Ren Star Unified Scale Score	0.77	0.02	<.001
Male Indicator	5.34	1.76	.002
Ethnicity: Hispanic/Latino Indicator	-7.69	1.78	<.001
Special Education Indicator	-11.08	3.13	<.001

Table 4. *Overall Impact of Imagine Math Facts on Spring 2023 Ren Star Math Unified Scale Score in Upper Elementary Grades*

Variables	Estimate	Standard Error	*p*-value
Intercept	260.21	15.44	<.001
Imagine Math Facts User Indicator	-0.90	1.47	.540
Grade-Level Indicator			
Grade 4	-2.28	2.05	.266
Grade 5	-10.08	2.44	<.001
Fall 2022 Ren Star Unified Scale Score	0.79	0.02	<.001
Male Indicator	1.58	1.51	.296
Ethnicity: Hispanic/Latino Indicator	-4.50	1.52	.003
Special Education Indicator	-15.93	2.71	<.001

DIFFERENTIAL IMPACT BY GRADE

A series of analyses were further conducted to examine how the effects of Imagine Math Facts varied across grade levels. Descriptive tables of unadjusted average Ren Star math Unified Scale scores by grade can be found in **Appendix A**, and tables demonstrating baseline equivalence by grade can be found in **Appendix B**. Grade 2 Imagine Math Facts users achieved statistically significantly higher Spring 2023 Ren Star math Unified Scale scores than comparable non-users; the difference is not statistically significant for students in other grades (**Table 5**). Complete regression results can be found in **Appendix C**.

Table 5. *Impact of Imagine Math Facts on Spring 2023 Ren Star Math Unified Scale Scores by Grade*

Grade	Estimate on Imagine Math Facts Indicator Variable	Standard Error	*p*-value
Grade 1	-0.55	2.38	.816
Grade 2	15.52	2.48	<.001
Grade 3	-1.09	2.55	.669
Grade 4	-1.67	2.48	.499
Grade 5	0.02	2.59	.994

Conclusion

Given the criticality of developing students' mathematics skill fluency (NMAP, 2008), it is imperative to understand the varying ways in which this can be best accomplished. Literature has pointed to the benefits of digital learning programs (Lindeman, 2019) to accomplish this. The results from this study corroborate and expand upon these findings.

Specifically, this study set out to examine the impact of Imagine Math Facts on the development of mathematics achievement of students in Grades 1–5. Overall, findings revealed a statistically significant impact on students' Renaissance Star math scores for students in early elementary grades. Early elementary students who used Imagine Math Facts scored 6.71 points higher on the Spring 2023 administration of the Renaissance Star mathematics assessment than did similar comparison students ($p < .001$).

A limitation of this study includes the relatively low average time spent in Imagine Math Facts among the treatment group. Recommendations from Imagine Learning suggest that Imagine Math Facts should be used as much as one hour per week throughout the school year, whereas students in this sample used it a total of 3.38 hours on average through the entire school year. Nevertheless, a statistically significant impact was found in lower elementary grade levels; this could be due to the fact that addition is the most completed operation, and addition could be most helpful in student growth on early elementary mathematics assessments focused on basic numeracy whereas higher grades may be assessed on more complex mathematical concepts and skills. More research is needed to determine the impact of Imagine Math Facts on math proficiency in upper elementary grade levels.

In summary, this study provides evidence of effectiveness of Imagine Math Facts on mathematics proficiency. Specifically, it demonstrates Imagine Math Facts' impact on the achievement of students in early elementary grades on the Renaissance Star mathematics assessment by comparing the outcomes of students who participated in the program to those who did not.

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Appendix A

Table A1. *Unadjusted Mean Ren Star Unified Scale Score by Grade Band*

	Fall 2022 (SD)	Spring 2023 (SD)	Mean Change
Grade 1			
Imagine Math Facts (n = 504)	791.29 (45.89)	861.98 (50.39)	70.69
Comparison (n = 504)	784.96 (48.27)	857.97 (53.96)	73.01
Grade 2			
Imagine Math Facts (n = 447)	860.43 (49.33)	931.99 (53.29)	71.56
Comparison (n = 447)	864.43 (49.20)	919.82 (59.23)	55.39
Grade 3			
Imagine Math Facts (n = 408)	927.16 (49.70)	990.51 (50.47)	63.36
Comparison (n = 408)	929.50 (49.57)	993.26 (54.95)	63.76
Grade 4			
Imagine Math Facts (n = 457)	985.19 (49.13)	1033.55 (57.20)	48.36
Comparison (n = 457)	986.83 (49.30)	1036.62 (58.65)	49.79
Grade 5			
Imagine Math Facts (n = 445)	1025.39 (50.16)	1058.42 (57.02)	33.03
Comparison (n = 445)	1026.95 (49.96)	1059.68 (57.78)	32.73
Lower Elementary (Combined Grades 1–2)			
Imagine Language & Literacy (*n* = 1,381)	823.79 (58.73)	894.89 (62.45)	71.10
Comparison (*n* = 1,381)	822.31 (62.81)	887.04 (64.36)	64.73
Upper Elementary (Combined Grades 3-5)			
Imagine Math Facts (n = 1,310)	980.77 (63.58)	1028.60 (61.63)	47.82
Comparison (n = 1,310)	982.60 (63.33)	1030.95 (63.28)	48.34

Appendix B

Table B1. *Grade 1 Baseline Equivalence*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	504	504		
Average (SD) Fall 2022 Ren Star Unified Scale Score	784.96 (48.27)	791.29 (45.89)	.033	0.134
Gender			>.999	<0.001
Female	253	253		
Male	251	251		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	251	251		
Yes	253	253		
Special Education			>.999	<0.001
No	465	465		
Yes	39	39		

Table B2. *Grade 2 Baseline Equivalence*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	447	447		
Average (SD) Fall 2022 Ren Star Unified Scale Score	864.43 (49.20)	860.43 (49.33)	.225	0.081
Gender			>.999	<0.001
Female	231	231		
Male	216	216		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	258	258		
Yes	189	189		
Special Education			>.999	<0.001
No	403	403		
Yes	44	44		

Table B3. *Grade 3 Baseline Equivalence*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	408	408		
Average (SD) Fall 2022 Ren Star Unified Scale Score	929.50 (49.57)	927.16 (49.70)	.499	0.047
Gender			>.999	<0.001
Female	216	216		
Male	192	192		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	249	249		
Yes	159	159		
Special Education			>.999	<0.001
No	368	368		
Yes	40	40		

Table B4. *Grade 4 Baseline Equivalence*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	457	457		
Average (SD) Fall 2022 Ren Star Unified Scale Score	986.83 (49.30)	985.19 (49.13)	.615	0.033
Gender			>.999	<0.001
Female	209	209		
Male	248	248		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	254	254		
Yes	203	203		
Special Education			>.999	<0.001
No	411	411		
Yes	46	46		

Table B5. *Grade 5 Baseline Equivalence*

Group	Comparison Students	Imagine Math Facts Students	*p*-value	Standardized Mean Difference (SMD)
n	445	445		
Average (SD) Fall 2022 Ren Star Unified Scale Score	1026.95 (49.96)	1025.39 (50.16)	.642	0.031
Gender			>.999	<0.001
Female	223	223		
Male	222	222		
Ethnicity: Hispanic/Latino			>.999	<0.001
No	236	236		
Yes	209	209		
Special Education			>.999	<0.001
No	405	405		
Yes	40	40		

Appendix C

Table C1. *Grade 1 Regression Results*

Variables	Estimate	Standard Error	*p*-value
Intercept	294.12	20.67	<.001
Imagine Math Facts User Indicator	-0.55	2.38	.816
Fall 2022 Ren Star Unified Scale Score	0.72	0.03	<.001
Male Indicator	8.17	2.41	.001
Ethnicity: Hispanic/Latino Indicator	-9.80	2.43	<.001
Special Education Indicator	-13.01	4.52	.004

Table C2. *Grade 2 Regression Results*

Variables	Estimate	Standard Error	*p*-value
Intercept	198.20	23.62	<.001
Imagine Math Facts User Indicator	15.52	2.48	<.001
Fall 2022 Ren Star Unified Scale Score	0.84	0.03	<.001
Male Indicator	1.48	2.54	.559
Ethnicity: Hispanic/Latino Indicator	-4.72	2.59	.070
Special Education Indicator	-7.55	4.30	.080

Table C3. *Grade 3 Regression Results*

Variables	Estimate	Standard Error	*p*-value
Intercept	336.24	26.56	<.001
Imagine Math Facts User Indicator	-1.09	2.55	.669
Fall 2022 Ren Star Unified Scale Score	0.71	0.03	<.001
Male Indicator	6.16	2.64	.020
Ethnicity: Hispanic/Latino Indicator	-0.88	2.69	.744
Special Education Indicator	-23.65	4.62	<.001

Table C4. *Grade 4 Regression Results*

Variables	Estimate	Standard Error	*p*-value
Intercept	201.41	28.03	<.001
Imagine Math Facts User Indicator	-1.67	2.48	.499
Fall 2022 Ren Star Unified Scale Score	0.85	0.03	<.001
Male Indicator	2.30	2.55	.366
Ethnicity: Hispanic/Latino Indicator	-4.76	2.55	.062
Special Education Indicator	-14.77	4.46	.001

Table C5. *Grade 5 Regression Results*

Variables	Estimate	Standard Error	*p*-value
Intercept	225.80	29.70	<.001
Imagine Math Facts User Indicator	0.02	2.59	.994
Fall 2022 Ren Star Unified Scale Score	0.82	0.03	<.001
Male Indicator	-3.36	2.64	.203
Ethnicity: Hispanic/Latino Indicator	-7.65	2.62	.004
Special Education Indicator	-8.88	4.97	.074

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