Frax

Technical Research Report

EFFICACY ANALYSIS OF FRAX

Sector I Year 2 Follow-up

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Table of Contents

Executive Summary

The current report presents the findings from Year 2 (2022-2023) of a longitudinal study of the impact of the Frax: Sector I program on the math achievement of matched groups of 3rd and 4th graders. Results from Year 1 of the study found that **usage of Frax by 3rd and 4th grade students during the 2021-2022 school year resulted in statistically significant gains in math achievement, including for the most academically at-risk students.**

The current report presents the second year of analysis for this cohort (Year 2), following the students into 4th and 5th grade and analyzing the continued impact of Frax usage on fractions knowledge and mathematics achievement by comparing them on Spring 2023 scores on their state math assessment.

Key findings include:

- Students who used Frax in Year 1 continued to outperform matched non-users into Year 2.
  - Frax users had significantly higher scores on fractions assessments and overall math achievement in Spring 2023 compared to matched non-users
- Usage of Frax in either Year 1 or Year 2 was significantly correlated to fractions knowledge in Spring 2023, even when controlling for baseline achievement scores (Fall 21).
  - The more students used the program, the higher their achievement scores were in Spring 2023.
- Students who were in the non-usage group in Year 1 but went on to complete the Frax program in Year 2 were able to fully catch up to or surpass their matched peers.
  - Students who did not use Frax in Year 1 but went on to become high Frax users in Year 2 had math scores in Spring 2023 (Year 2) that were identical to matched Year 1 high users, and statistically significantly outscored matched Year 1 low users from the original treatment group.
- Frax users continued to meet grade-level proficiency expectations at higher rates than matched non-users, especially for the most academically at-risk students.
  - Students who were two or more grade levels below at the beginning of Year 1 and had high Frax usage were significantly more likely to approach or meet grade-level proficiency compared to matched non-users.

Overall, the current study found that **the achievement gains associated with Frax usage in Year 1 were sustained, as measured via performance on a standards achievement test in Year 2.** Importantly, control students who were exposed to Frax in Year 2 also showed achievement gains, fully catching up to or exceeding their peers and closing any achievement gaps observed in Year 1. This evidence demonstrates that Frax Sector 1 is an effective and efficient intervention with a lasting impact on students' mastery of fractions and grade-level standards in mathematics, and can be used well into 5th grade to help close math achievement gaps.

Introduction

Performance with fractions has been a weak point in U.S. education for decades and has not improved in recent years (Siegler, 2017). Building a strong foundation of early fractions knowledge is critical to later mathematical success. In a recent national survey of 1,000 Algebra teachers, most rated students' knowledge of fractions as "poor" and rated fractions as one of the top two barriers to students mastering algebra (Hoffer et al., 2007). Additionally, fractions knowledge in grade five uniquely predicts students' mathematics achievement in high school. This is true even after controlling for other variables like general intellectual ability, working memory, and family income and education levels (Siegler et al., 2012), making interventions to support early fractions learning an important and effective way to support later academic achievement.

ExploreLearning Frax is a standards-aligned program designed to support fractions learning for students in grades 3-5 using research-proven instructional methods. Game-based and story-driven, Frax invites students to travel through space on engaging and standards-based missions that motivate and incentivize student-driven learning. Students earn rewards and tokens as they play, which they can use to personalize their virtual living quarters on the ship. It uses innovative adaptive technology that delivers different levels of support to different students depending on their progress, making it effective for both struggling students and those needing extra practice via a learning path that is unique to their skills and abilities. Frax also provides real-time data to show teachers when a student is struggling so that they can intervene.

The current report details the findings from the second year of a longitudinal efficacy analysis of Frax Sector I as a digital complement to the existing math curriculum in a large, suburban public school district in Florida. Sector I, broadly aligned to grade 3 fractions standards, is centered on the conceptual understanding that fractions are numbers with magnitude just like any other number and builds a foundation for learning fractions arithmetic[1]. Sector I is designed as a zero-entry program, so that students with no previous knowledge of fractions can begin using the program immediately. The goal of the study was to measure the long-term impact of Frax on student achievement through a quasi-experimental method that supports causal inferences, building on our initial positive findings from the cohort in Year 1.

Analyses in Year 1 provided promising support for the use of the Frax program as an intervention program to support all students in learning fractions, and as a result improve overall math performance. Frax was found to be 3x more effective than the average educational intervention for 3rd graders and 5x more effective than the average educational intervention for 4th graders. Students who used Frax with fidelity were significantly more likely to reach grade-level proficiency in the spring compared to matched non-users who were identical at baseline. Even academically at-risk students who used Frax were 2x more likely to reach grade level proficiency in the spring compared to matched non-users.

[1] Frax Sector II, aligned to 4th grade standards, was released in March 2023. No students in the current sample had access to Sector II at the time of data collection.

The following analyses include data from all of the Year 1 students that we were able to follow into Year 2. This data set includes 2,109 matched pairs of 4th and 5th grade students, half of whom used Frax in Year 1. Some of the students in the original control group went on to use Frax in the 2022-2023 school year, which gives us the ability to compare student growth with different exposure points. Dependent variables used in the current study include both i-Ready Diagnostic math assessment as well as a newly implemented state-wide diagnostic math assessment (Florida Assessment of Student Thinking) that includes a fractions assessment and was administered for the first time in Spring 2023.

This study was designed to meet the Every Student Succeeds Act (ESSA) Tier 2 (Moderate) rating on the ESSA guidelines for evidence-based interventions. The study uses quasi-experimental matching methods to create baseline equivalency between treatment and control groups along major confounding factors.

Methodology and Sample

Independent Variable: Frax: Sector I

Frax is an adaptive, game-based, online program for students in grades 3–5 to help all students learn fractions. Frax Sector I is designed as a zero-entry program so that students with no previous knowledge of fractions can begin using Frax immediately. Frax automatically recognizes and delivers different levels of support to different students depending on what they need to progress. As students navigate Frax's game-based activities, and based on their specific interactions, the program adapts to what they demonstrate they do not know and reinforces skills as needed for students to begin making sense of fractions concepts. There is also hinting functionality for students who are struggling with a particular question. These features create individualized, efficient instruction that intentionally moves each student forward on a customized path by continuously adapting and scaffolding instruction based on how they interact with the program.

The Frax approach teaches students that fractions are numbers. Students learn that fractions have a magnitude (size) and expand the number system beyond whole numbers in useful ways. Students practice these concepts in Frax through explicit, scaffolded use of length models, number lines, and measurements that help broaden their understanding of numbers, or number sense, to include fractions. By building conceptual understanding of fraction magnitude, students build the foundation they need to move beyond memorized procedures and tricks and instead learn to make sense of fractions arithmetic. They compare fractions once they understand the magnitude of unit fractions and the other fractions that are made up by unit fractions.

Frax is continually assessing and monitoring students' progress formatively rather than using separate summative assessment activities. Because missions are adaptive, the questions in each mission will be tailored to students' performance which supports and maintains student engagement and motivation. Thus, progress through the successive missions is the best demonstration of student growth, and the metric used in the current study. Frax missions typically require 20–30 minutes to complete. Missions must be completed in order and students are limited to completing one mission per day.

Dependent Variables: i-Ready Diagnostic and State Math Diagnostic Assessment

From Fall 2021 through Fall 2022, i-Ready Diagnostics were used to assess student's mathematics achievement. In all the analyses here, overall math scale scores were used to provide the most stringent test of the impact of Frax on student's overall ability to perform grade-level mathematics.

At both fall and spring, i-Ready classifies students' into one of three criterion-referenced grade-level placements based on scale scores: current grade level or above, 1 grade level below, or two or more grade levels below. The current grade level placement is further divided into three range levels: early, mid, and late. By the end of the school year (spring testing), students are considered proficient for their grade (i.e., have met the minimum requirements) only if they fall within the mid, late, or above grade ranges.

In Spring 2023, the district switched from using i-Ready to a state-specific diagnostic math assessment tool: the Florida Assessment of Student Thinking (FAST) test. While the measure differs slightly from i-Ready in the specific insights it provides, many of the variables remain similar. Overall math scale scores were reported, as well as achievement levels for demonstrated mastery of state standards based on scale scores: below grade level performance (levels 1 and 2), on-grade level performance (level 3), and above grade level performance (levels 4 and 5). In addition, the test reports a score for "Number Sense and Operations with Fractions and Decimals" which is used in the current study to assess student's fractions knowledge.

In the current study, academic performance in Year 2 was assessed by statistically comparing matched users and non-users on Spring 2023 fractions assessment scores, overall math scale scores, and relative achievement levels.

Case Control Matching to Create Equivalent Groups

While true randomized experiments (i.e. students each randomly assigned to either the control or the experimental condition) are often seen as the "gold standard" in research for determining causal relationships between interventions and outcomes, randomization in a school setting can often be difficult. Here, we use a quasi-experimental design to account for pre-existing differences between groups and support causal inferences between the intervention (Frax usage) and the outcome (change in math achievement scores from baseline to post-test). The statistical package SPSS was used to create case-control matches of a student with Frax usage in Year 1 (treatment group) to a very similar student with no Frax usage in Year 1 (control group).

Students were matched on 2021-2022 grade level (3rd or 4th), Fall 2021 i-Ready diagnostic math scores (within 5 scale score points), and current and prior Reflex program usage (within 5 days usage)[2]. Mean i-Ready Fall 2021 (pretest) math scores between treatment and control groups differed by .04 scale score points and satisfies WWC standards for baseline equivalence.

Study Sample

The students come from a large, suburban public school district in Florida. The district has over 97,000 students across over 100 schools. The district's minority enrollment is over 60% and 35% of students are economically disadvantaged.

The matched pairs that were established in Year 1 of the research study were also used in Year 2 to analyze student growth from Frax usage. The current study sample includes all pairs of students from Year 1 who we had data for in Year 2, resulting in a final sample of 2,109 4th and 5th grade students who used Frax Sector I in Year 1, and a matched control group of 2,109 4th and 5th grade students who did not use Frax in Year 1. Table 1 provides a full breakdown of sample demographics.

Table 1: Breakdown of Sample Characteristics

	Treatment (Frax use in Year 1)	Control (No Frax use in Year 1)
Total N's	2,109	2,109
Fall 2021 Math Scale Score: M (SD)	440.67 (23.44)	440.63 (23.40)
Fall 2021 placement levels: n (%)		
2+ grade levels below	398 (18.9%)	404 (19.2%)
1 grade levels below	1269 (60.2%)	1243 (58.9%)
Early-on grade and above	442 (20.9%)	462 (21.9%)
Grades (2022-2023 school year)		
Grade 4	1000	1000
Grade 5	1109	1109
Demographics: n (%)		
Male	1053 (49.9%)	993 (47.1%)
Female	1053 (49.9%)	1113 (52.8%)
Hispanic/Latino	718 (34%)	773 (36.7%)
Black/African American	351 (16.6%)	308 (14.6%)

The Frax Sector I program contains 27 missions, and student progress is quantified here as the number of missions completed. Usage in Year 1 identified three completion rate bands for analyses: low Frax completion (1-10 missions completed), moderate Frax completion (11-19 missions completed), and high Frax completion (20-27 missions completed).

[2] This district is also a user of another ExploreLearning math program, Reflex. Reflex is a game-based program that supports math fact fluency. In order to isolate the effects of the Frax program in the current study, we matched students on number of days usage of Reflex in the prior and current school years. Thus, we can be confident that the current report shows the impact of Frax usage above and beyond and impact from Reflex. Additional reports on Reflex efficacy can be found at https://explorelearning.com/

In Year 2, all students continued to have access to Frax, and treatment students could have progressed farther in the program than they did in Year 1. Also, about half of the original control group (1,140 students) went on to use Frax in Year 2. Table 2 presents details of the number of matched pairs of students who fell into each of the corresponding usage band categories, reflecting both the Year 1 groupings (treatment vs control) and the Year 2 Usage (No usage, low completion, moderate completion, high completion). Due to low sample sizes in many of the categories, 4th and 5th grade students were analyzed together in the following analyses. Based on the findings from Year 1 (i.e., significant differences only for high Frax completion group) the majority of analyses focus on comparing the high completion treatment group students to control group students that remained in the no Frax usage (n = 298 pairs of matched students).

Table 2: Frax usage in Years 1 and 2 by students in the original (Year 1) control and treatment groups (N = number of matched pairs of students)

Treatment Group (Frax usage in Year 1)	Control group (no Frax usage year 1)			
	No Frax Usage in Year 2	Low Frax completion (1-10) in Year 2	Moderate Frax completion (11-19) in Year 2	High Frax completion (20-27 missions) in Year 2
Low Frax completion (1-10) by end of Year 2	453	327	69	77
Moderate Frax completion (11-19) by end of Year 2	218	175	48	47
High Frax completion (20-27 missions) by end of Year 2	298	247	69	81

Results

Frax Usage and Spring 2023 Math Scores

Paired-samples t-tests were used to compare fractions assessment scores and math scale scores in Spring 2023 for the pairs of baseline matched users. Standardized effect sizes (Hedge's g) were used to estimate the size of the difference between the treatment and the control groups.

In Year 1, we found that fidelity Frax users (completing 20+ missions) gained significantly more points between fall and spring i-Ready assessments compared to matched students with no Frax usage. Similarly, in Year 2, paired-samples t-tests showed that high Frax users (completing 20+ missions) outperformed matched students with no Frax usage on the overall math scale score, $t(297) = 4.92$, $p < .001$, $d = .29$ (See Table 3). As in Year 1, there was no significant difference between math scale scores for matched users and non-users with low (1-10 missions) or moderate (11-19 missions) Frax completion (both p's > .05).

Table 3: Differences in spring 2023 math achievement between high-completion Frax users (20+ missions) and matched non-users

	Treatment (high completion)	Control (no Frax usage)	Difference	Effect Size (Hedge's g)
Fractions Assessment Scale Score	228.25	220.96	7.29***	.23
Spring 2023 Overall Math Scale Score	226.06	220.25	5.81***	.29

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

Frax Usage in the Control Group and Spring 2023 Math Scores

Partial correlation analyses controlling for baseline math achievement (Fall 2021 math scores) found that usage of Frax at any time between 2021 and 2023 was significantly correlated to fractions knowledge for students in the original treatment group, with further progress in the program resulting in higher scores on the fractions assessment, $r(2106) = .153$, $p < .001$. This relationship was also found for students in the original control group who went on to use Frax in the 2022-2023 school year (Year 2), $r(1137) = .190$, $p < .001$.

To further test the hypothesis that Frax usage leads to improvements in math performance, we conducted paired samples t-tests comparing students in the original treatment group with high or low Frax completion with their matched students from the original control groups (no Frax usage in Year 1) who went on to have either no or high Frax completion in Year 2. If Frax is responsible for improved math performance, we should see a pattern of results such that high Frax completion results in outpaced performance compared to students with no or very low Frax completion, regardless of when that exposure took place. Several control group students with no Frax usage in 2021-2022 went on to have high Frax completion (20+ missions) in 2022-2023 (n = 205), making this test possible. The results of these tests are shown in Table 4.

Table 4: Mean differences in Spring 2023 math scale scores between matched treatment group and control group students accounting for Year 2 Frax usage

Treatment Group (Frax usage in Year 1)		Control Group (no Frax usage in Year 1)	
		No Frax usage	High Frax completion in 22-23 (20+ missions)
Low Frax completion (1-10 missions)	Fractions Scale Score	n.s.	-10.71***
	Math Scale Score	n.s.	-9.25***
High Frax completion (20+ missions)	Fractions Scale Score	7.29***	n.s.
	Math Scale Score	5.81***	n.s.

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

Students with high Frax usage outperformed the matched students with no Frax usage (as also shown above in Table 3). Importantly, **students from the Year 1 control group who went on to have high completion of Frax in Year 2 scored statistically the same as matched high treatment group users** (both p's > .39). Thus, for these students, usage of Frax in Year 2 helped them to close the achievement gap and catch up to those students who experienced significantly higher growth in Year 1. Additionally, **control users from Year 1 who went on to have high completion of Frax in Year 2 outperformed matched low completion users from the Year 1 treatment group in both fractions assessment scale scores and math overall scale scores** (both p's < .001).

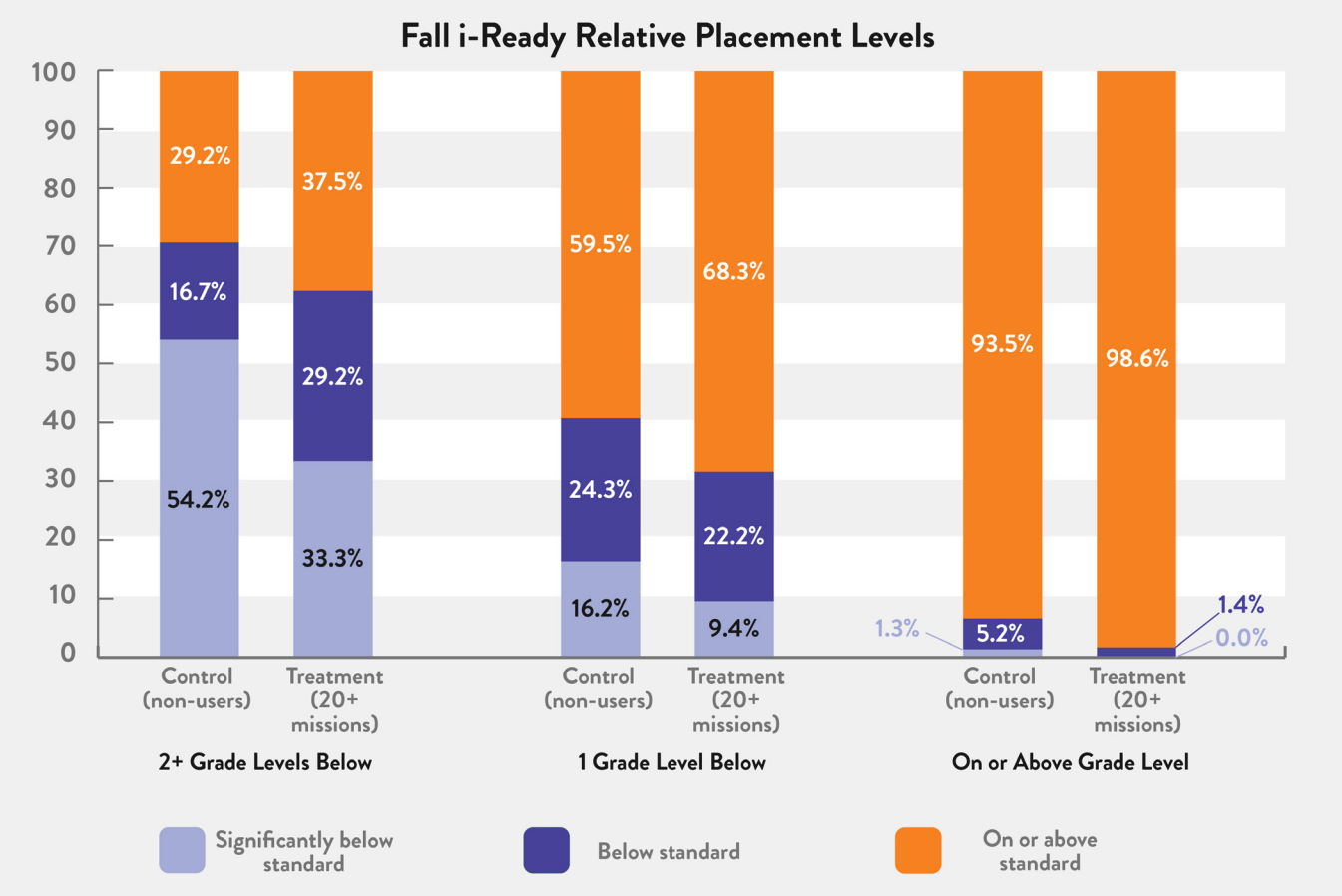
Even though Frax Sector I is tailored for 3rd grade standards, these findings suggest that exposure to Frax Sector I into 4th and even 5th grade can still be beneficial for improving fractions knowledge and overall math performance, helping to close the achievement gap between control and treatment users in Year 2.

Frax Usage and Meeting Grade Level Proficiency

The next set of analyses looked at the relationship between Frax usage and likelihood of meeting or exceeding grade-level proficiency by the end of the school year. Our results in Year 2 largely mirrored those found in Year 1; **only 63% of students in the control group (no Frax usage) met or exceeded grade-level expectations in Spring 2023, compared to 70% of matched users with high Frax completion rates,** chi-square χ^2 (1, N = 596) = 3.34, p = .034.

Figure 1 shows the mobility across specific Placement levels from fall to spring for students with no Frax usage compared to matched students with high Frax completion. **Within every baseline student placement category (2+ grade levels below, 1 grade level below, on grade level or above), Frax usage was related to increased performance nearly two years later. This effect was particularly pronounced for the most at-risk students in the group: those scoring 2+ grade levels below in Fall 2021.** Among this group of matched students, 54% of the control students who placed 2 or more grade levels below in Fall 2021 remained significantly below standards in Spring 2023 compared to only 33% of high Frax users, chi-square χ^2 (1, N = 96) = 4.23, p = .020. Additionally, 38% of high Frax users who placed 2 or more grade levels below in Fall 2021 achieved grade level proficiency by Spring 2023, compared to only 29% of matched non-users.

Figure 1: Spring 2023 state math test relative placement levels based on fall 2021 i-Ready relative placement levels for control students (0 missions) vs matched treatment students (20+ missions).



Conclusions

The current analysis provides evidence of the positive impact of the Frax Sector I program on student math achievement. Performance with fractions has been a weak point in U.S. education for decades (Siegler, 2017) and building a strong foundation of early fractions knowledge is critical to later mathematical success (Hoffer et al., 2007). The current study built upon the knowledge gained from our Year 1 analysis of a large sample of over 5,000 case-control matched 3rd and 4th grade students, showing that less than 13 hours of classroom usage of Frax led to statistically significant improvements in academic growth between fall and spring administrations of a diagnostic math test.

Our results here showed that the benefits of the Frax program observed in Year 1 were maintained in Year 2, with those matched students who used Frax in Year 1 continuing to show significantly higher academic performance on standardized mathematics achievement tests compared to baseline matched students who did not use Frax over a year after program usage. This finding aligns with prior research which found that supporting fractions knowledge supports numerical procedures performance more broadly, closing the achievement gap between at-risk students and typically achieving students (Fuchs et al., 2013).

Frax usage led to sustained improvement in math skills for even the most academically at-risk students in the study. Over half (54%) of students who placed two or more grade levels below standards in Fall 2021 and did not use Frax remained significantly below standards nearly two years later in Spring 2023. However, only one-third (33%) of the students who were identical to them but had high Frax completion remained in this category in Spring 2023. Similar trends were observed in the other groups of students as well, with high Frax users being significantly more likely to meet or exceed grade-level standards compared to their matched non-users. Importantly, this difference was observed over a year after Frax usage.

The results showing sustained differences between baseline-matched users and non-users over a year after Frax usage suggests that an intervention is necessary for non-users to "catch up" and close the achievement gap between the groups. We tested this by looking at two additional groups of students compared to their baseline matched users: (1) students in the original control group who went on to have high Frax usage in Year 2 compared to their matched students with high usage in Year 1 and (2) students in the original control group who went on to have high Frax usage in Year 2 compared to their original matched students with lower Frax usage in Year 1.

The pattern of findings here shows additional support for the hypothesis that Frax usage leads to student improvement. In the first analysis, we found no statistical difference between matched students when they both had high Frax usage, suggesting that usage in year 2 helped control students close the achievement gap and catch up to students with earlier Frax usage. In the second analysis, the original control students who had high Frax usage in Year 2 that surpassed the matched treatment condition students who only had low usage in Year 1 scored significantly higher on math achievement testing in Spring 2023. This shows that high Frax program usage even into 5th grade was beneficial for these students who previously did not have a chance to use Frax, catching up to or surpassing their matched peers.

A recent longitudinal report from Cambium Assessment found significant learning loss among students in math, with the number of students observed on-grade level in mathematics dropping as much as 21 percentage points (Cambium Assessment, 2022). Reports such as this one have led to widespread concerns over helping students recover from learning loss. **The current study found that just a few hours of Frax usage supported higher math achievement over a year post usage and contributed to upward math achievement mobility for those students most at-risk, strongly supporting its use as a math recovery tool for all students.**

About ExploreLearning

ExploreLearning LLC, based in Charlottesville, VA, was founded in 1999 by educators looking for new ways to inspire students across grades K–12 and help them succeed in math and science. With a philosophy of life-long learning driving our thought leadership, a careful attention to the current needs of educators in today's rapidly-shifting educational culture, and a legacy of proven results, ExploreLearning is the best combination of proven expertise and innovative solutions over time to meet today's and tomorrow's educational challenges.

Our four digital programs (Reflex®, Frax®, Science4Us®, and Gizmos®) are currently used in classrooms in every state in the U.S. and more than 80 countries worldwide. Our programs are state- and national-standards aligned, including Next Generation Science Standards (NGSS) and the Standards for Mathematical Practice (SMP). ExploreLearning is a recognized leader in the educational software market, earning many major edtech awards.

We aim to foster student success through the use of galvanizing, age-appropriate multimedia, including interactive simulations, STEM case studies, adaptive games, instructional videos, and much more. Our development team of engineers, researchers, and instructional-design experts, most of whom are former educators, are continually innovating beyond the latest advancements in instructional pedagogy and edtech. Our programs support students in developing mastery of fundamental skills and deep conceptual understanding in math and science, while also fully engaging them in the process of internalized learning, promoting growth mindset, resiliency, productive struggle, and perseverance.

Our goal is to provide educators with captivating, best-in-class digital learning in math and science that helps students reach their full potential. We firmly believe that teachers are mission-critical, i.e., the greatest influence on student success. We also believe that data, instruction, and practice, when operating in tandem, are paramount to improving student learning and academic achievement. In support of these foundational beliefs, we deliver curricula, professional learning, and implementation and technical support services that:

- Combine research-proven instructional methods and innovative technology
- Enable equitable access to math and science learning for all students
- Build strong, lasting foundations for student success by developing procedural and conceptual understanding
- Supplement core curricula with flexible digital and blended implementation
- Create positive outcomes and results for both students and teachers

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