Insights for educators

Fractions knowledge growth for students using Amplify Fractions

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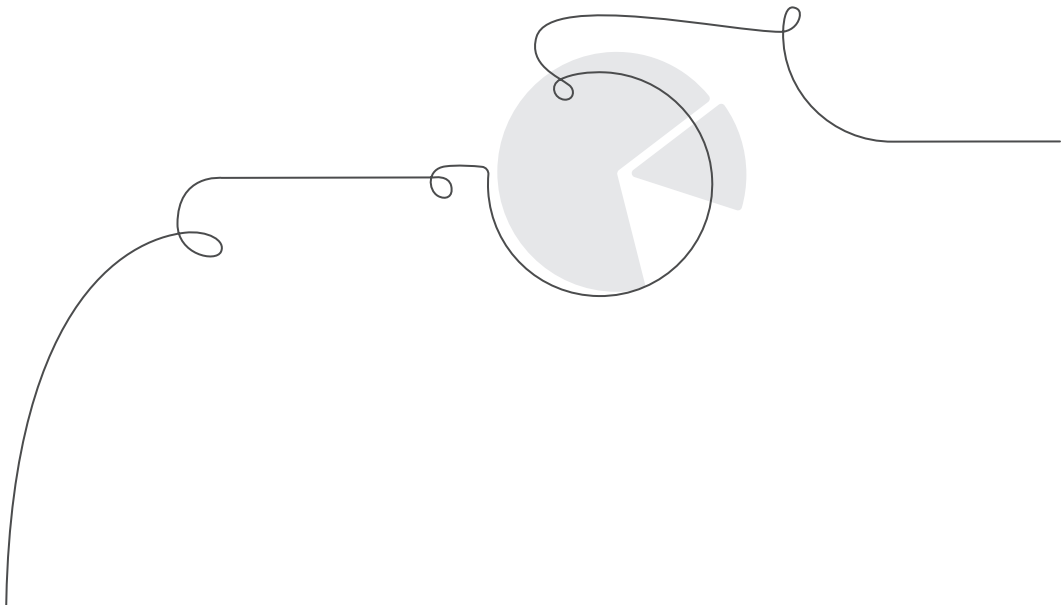
Amplify.

Introduction

This paper describes a study of learning growth for students using Amplify Fractions based on a pre-post analysis. The study was designed as a test of the product's theory of action, that is, that students using Amplify Fractions should substantially improve their fractions knowledge. Specifically, a stand-alone assessment was created in such a way as to give an equally difficult assessment of student knowledge at both pre- and posttest administrations. Also, analytic methods were used to address alternative explanations for student growth.



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Amplify Fractions is a supplemental digital program from Amplify Education, Inc. that blends narratives with interactive moments, offers personalized feedback, and provides low-stakes adaptive practice.

The product consists of 51 interactive lessons, each with a corresponding adaptive practice module. Lessons were designed in alignment with a strong theory of Learning Progressions in this area. The Learning Progressions are also aligned with the Common Core State Standards for Mathematics in Grades 3–6. Amplify Fractions reports include overall mastery determinations as well a breakdown of performance by standard. In addition, the lessons are organized into 3 sets covering:

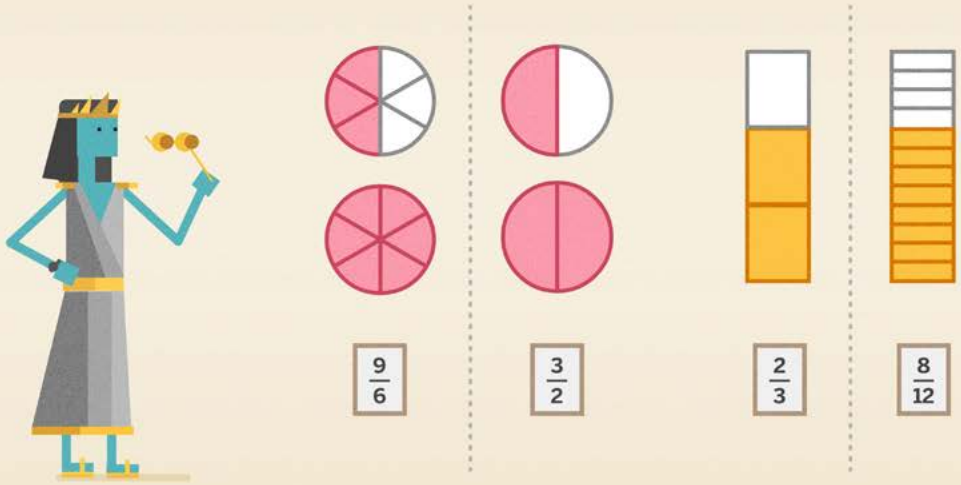
- Intro to Fractions (15 lessons);
- Equivalence & Comparison, Adding & Subtracting (17 lessons); and
- Multiplying & Dividing (19 lessons).

The first set reviews division, introduces fractions as numbers, defines notation, discusses "proper" versus "improper" fractions (while observing how petty this distinction is), introduces mixed numbers, and covers locating fractions on the number line. The remaining two sets cover equivalence and comparison, as well as the operations of addition, subtraction, multiplication, and division.

Lessons in Amplify Fractions blend animated narratives with highly personalized feedback. In each lesson, students encounter one of several storylines (e.g., the Carnivorous Jungle and Bob Da Vinci's Workshop). Each lesson advances the storyline, keeping students engaged while they answer fractions-related questions along the way. The lessons also provide students with different questions and explanations, depending on the answers they give and the choices they make within the lesson. In addition, a digital tutor provides feedback tailored to the students' answer choices.

Lessons and their practice modules are organized according to Amplify's Learning Progressions for fractions. The Learning Progressions provide a rich framework for student learning, and describe not only learning targets, but also the multiple pathways students can take to reach those targets. The Learning Progressions are aligned with the Common Core State Standards for Mathematics in Grades 3–6 and cover the Grades 3–6 strands related to Numbers & Operations—Fractions and The Number System.

Amplify Fractions has been designed using foundational and research-based pedagogical strategies. Specifically, Amplify Fractions includes: (1) feedback that is personalized to each student and how they think about the mathematics, (2) story-driven instruction designed to keep students engaged and motivated, and (3) a scope and sequence that completely covers fractions standards, tied to learning progressions.



Study design

Students using Amplify Fractions were administered pre- and posttests to assess their growth in fractions knowledge. Results of these tests were analyzed to address the following research questions:

1. What are the psychometric properties of the pre- and posttest forms?
2. To what extent did Amplify Fractions users demonstrate growth in fractions knowledge?
3. Was increased usage associated with more fractions knowledge growth?
4. Was fractions knowledge growth explainable by the simple passage of time rather than usage?

These questions focus on whether students demonstrated growth, and whether that growth was reasonably attributable to using Amplify Fractions. Specifically, in answer to question 3, if Amplify Fractions is driving growth, we would expect to see higher growth associated with higher usage. If not, that would suggest that growth is actually resulting from a different process.

Question 4 addresses a more complex challenge. Specifically, given more time in classrooms where teachers are teaching fractions, students are likely to have more growth and also more usage, even if usage isn't the actual cause of growth. This research question assesses whether this alternative explanation is consistent with the data, or whether product usage is the better explanation of the growth observed.

Method

Participants

A total of 2,183 students completed the pretest and 411 completed the posttest between August 1, 2018 and January 3, 2019. The students included in this analysis completed more than half of test items. Students represented schools from around the country, with no more than 62 from any one district. Table 1 shows the 10 districts with the most students completing both a pretest and a posttest.

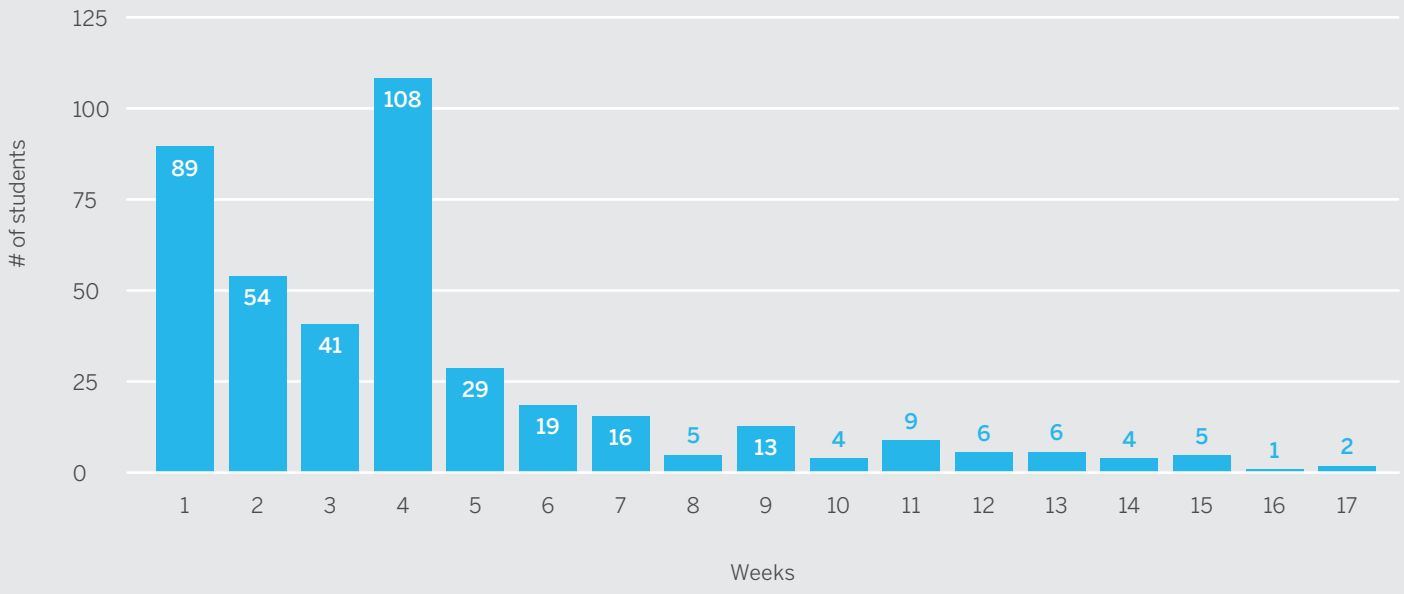
The amount of time elapsed between the pretest and posttest varied considerably, with an average of 23.4 days (sd = 23.5) between completing the pretest and beginning the posttest. The distribution of time elapsed between tests can be seen in Figure 1, below.

Table 1. Top 10 participating districts

City, State	Count
Lake Jackson, Texas	62
Hazel Park, Michigan	42
Providence, Rhode Island	39
Warren, Ohio	39
Mount Laurel, New Jersey	36
Skokie, Illinois	27
Arlington, Virginia	26
Harrisburg, Pennsylvania	20
Olympia, Washington	19
Redwood City, California	19

Figure 1. Amount of time between pretest and posttest

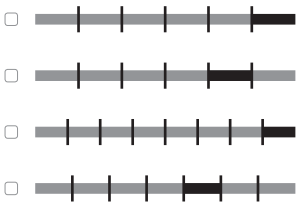
Students completed an average of 7.3 lessons (sd=6.71) between the pre- and posttest.



Instruments

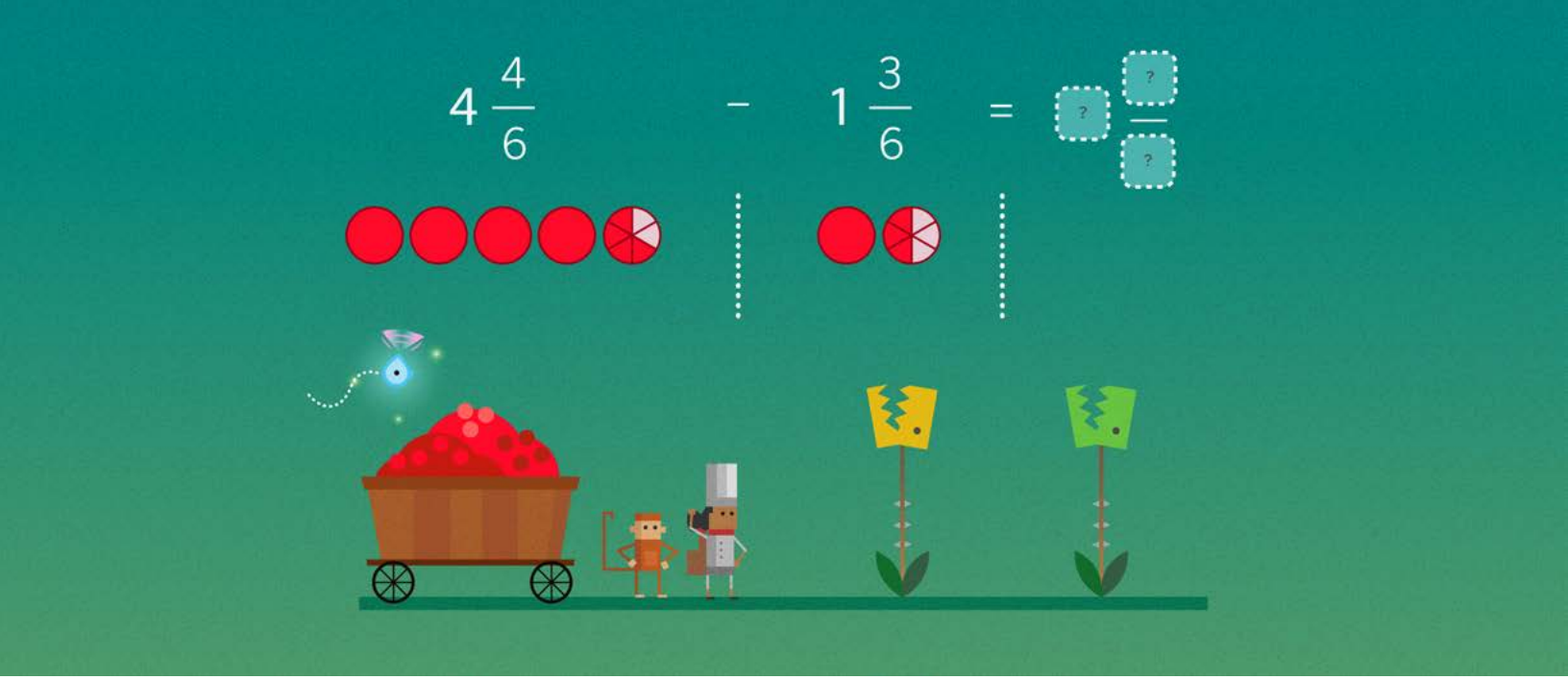
Four equivalent forms of 15 items each were assembled from a pool of 30 items. The forms were designed to be used in pairs: one as a pretest, and the other as a posttest. The forms were created such that all of the forms could be placed on a common scale, and so that students could take a pair of forms without seeing the same question twice.

The four forms were designed to measure a breadth of content understanding, and included original items as well as released items from well-known standardized tests (TIMSS, NAEP, PARCC, and SBAC). First and foremost, the test forms were designed to assess the three Learning Progression Levels (LPLs) of the Fractions learning progression, covered by the the first set of 15 lessons. When released items from standardized tests could achieve this goal, those items were used. Released items make up 20% of the total item pool. The remaining items in the pool were authored by content experts according to the specifications of Learning Progression Level Outcome Cases (LPOCs) for each LPL. The LPOCs specify distinct outcomes within each LPL, thus supporting valid question authoring. Two example items and their specifications according to the LPOCs are shown below.

	Example A: Original item	Example B: Released NAEP item
LPL	A1: Representing unit fractions with area and length models.	A2: Representing non-unit fractions with area and length models.
LPOC	e5: Recognizing that equipartitioning a segment can be represented as division, and all shares are equal to the same unit fraction.	e1: Symbolically representing proper fractions relative to area models.
	The elders determined that each tribe member should search $\frac{1}{6}$ of a road for resources. Each segment represents 1 whole road. Which **two** of the roads have a shaded part showing 1 tribe member's search area?  Check Answer	What fraction of the figure is shaded?  Check Answer

Administration

During the fall semester of the 2018–2019 academic year, students who logged in to Amplify Fractions could self-select to take the pretest at any point. After completing the pretest, students had the option to take the posttest—again, at any point. All the while, students were able to access the lessons and practice within the product.



Results

Psychometrics

1. What are the psychometric properties of the pre- and posttest forms?

First, the Classical Item Difficulties for each item were evaluated. Rules of thumb state that when 20%–80% of students are able to answer the item correctly, the item is appropriately challenging. Three items were flagged for removal because less than 20% or more than 80% of students answered them correctly. Next, the 2,183 responses to the forms used as pretests were calibrated using a Rasch model. Responses to the forms used as posttests were also calibrated using a Rasch model. The item fit indices for each item in each form were examined. Items with large fit indices are known to distort the measurement system (Linacre, 2002). No additional items were flagged for removal due to poor fit.

After separate calibrations, forms were equated using Fixed Common Item Parameter Equating (FCIP) with the pretest as the reference test. The FCIP procedure placed the forms on the same scale so that growth between pre and post could be tracked on a common scale (for a description of FCIP and other common item equating procedures see Kim, 2006).

The final forms had strong reliabilities, with an average internal consistency reliability of 0.80, and individual forms having reliabilities of 0.78, 0.81, 0.77, and 0.83. The final item parameters and their fit indices are shown in Appendix A: Item statistics.

Growth analyses

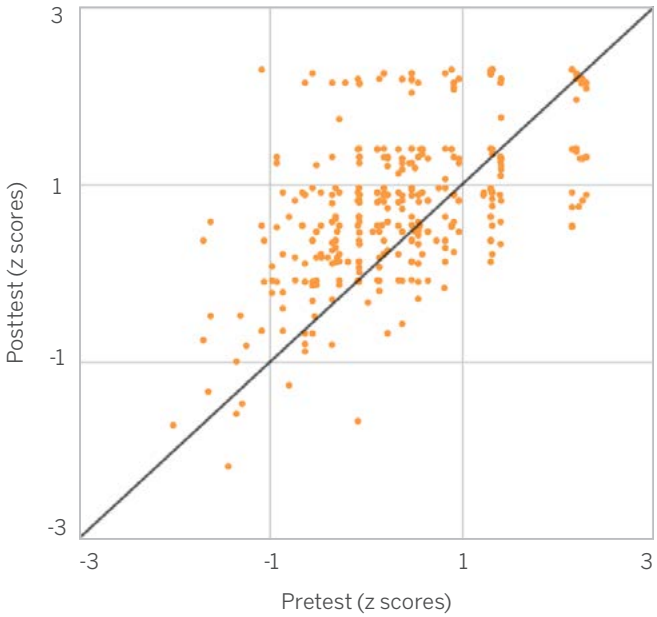
2. To what extent did Amplify Fractions users demonstrate growth in fractions knowledge?

In order to look at growth associated with using the program, we focused on students who demonstrated a meaningful use of the program. So, we analyzed results for students who completed five or more lessons and used the program for one week or more between the pretest and posttest. This left 216 students of the original 411 who took the posttest. All 216 students received pretest and posttest ability estimates from the equated forms. For easier interpretation, we transformed the ability estimates into standardized scores (i.e., z scores with mean=0 and sd=1) based on the population distribution estimates from the reference form. All results discussed in this paper refer to standardized scores.

To assess the extent of growth for Amplify fractions users, we compared pretest and posttest scores for students who used the product beyond the minimal threshold (five or more lessons and more than one week of use). The pretest score mean was 0.36 (sd=.83), while posttest score mean was 0.93 (sd=.74).[1] On average, then, students using the product gained 0.57 standard units (sd=.80), which is also the effect size. A t-test comparing pre- and posttest results found this change to be significant (t=10.49, df=215, p<0.001). In terms of percent correct, the pretest mean was 69% and the posttest mean was 78%. The pretest median was 69% and the posttest median was 83%. Thus, students demonstrated significantly higher knowledge of fractions after using Amplify Fractions. The effect size of +0.57 would be rated Moderate (Cohen, 1988), and would be the equivalent, on average, of moving a student from the 50th percentile to the 72nd percentile.

Figure 2 shows a plot of pretest performance against posttest performance. Note that the diagonal line indicates when a pretest score and a posttest score were equal. Scores above the line reflect positive change (i.e., growth) between the pretest and posttest, while those below the line reflect a decline in performance between the pretest and posttest. The trend for positive growth thus is indicated by the bulk of scores falling above the line. The main exception was that students who scored high on the pretest (at or near the maximum) were much more likely to decline on the posttest. This can be observed in the upper right part of the chart. Notice that there is very little room for growth for these students, so random error is likely to push some of them below the line. This pattern suggests that a ceiling effect on the test likely prevented some students from showing growth. Future research using more difficult tests may be likely to show growth even for advanced students.

Figure 2. Fractions pretest vs posttest scores

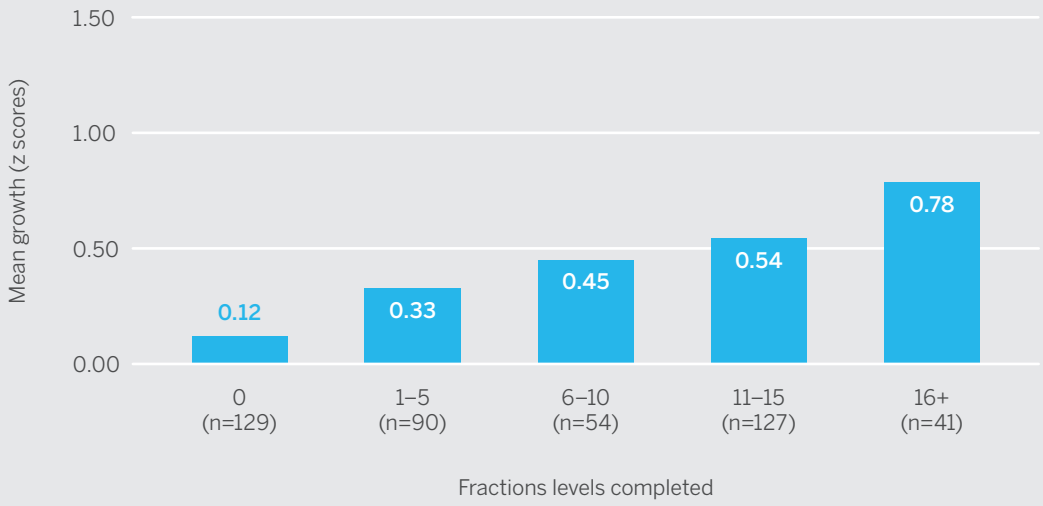


1 Note that the mean for all pretest takers was set at 0, so students who took both the pretest and posttest had higher pretest scores than the average (0.36 vs. 0.00).

3. Was increased usage associated with greater fractions knowledge growth?

We explored the results in two ways to assess whether it was appropriate to attribute higher growth to product use. That is, if students were learning as a result of using the product, we would expect to see greater growth associated with greater product usage. Figure 3 displays the average growth by the number of lessons completed between pre- and posttest.

Figure 3. Growth by number of episodes completed



Note the strong upward trend with greater improvement as the number of lessons increase. That is, the more lessons students completed, the larger their average growth. Those with the highest usage, 16 or more lessons, averaged a growth of 0.78 sds, while those who did not complete any lessons only grew an average of 0.12 sds. Thus, the trend was consistent with the hypothesis that usage was supporting additional growth.

4. Was growth explainable by the simple passage of time rather than usage?

We also explored whether improvement was driven more by the simple passage of time than by product usage. Given that students were likely to have received instruction on fractions in their regular class time as well as on Amplify Fractions, we wanted to test whether the positive results could have been driven by regular instruction rather than usage of the product. To examine this issue, we conducted a series of regression analyses, examining growth as a function of time (measured in weeks between the pretest and posttest) and product usage (measured as lessons completed between the pretest and posttest).

The first two regression models examined whether growth was associated with increased Time (Model 1) or Usage (Model 2) separately. The estimates from Model 1 found that the number of weeks between tests was significant predictor of growth, with each week of instruction corresponding with 0.04 sds of growth. The estimates from Model 2 show that completion of an additional lesson was associated with growth of 0.03 sds. So, treating Time and Usage separately, each predicted higher growth.

Table 2. Regression models predicting fractions knowledge growth (pretest to posttest, z-score units)

	Model 1	Model 2	Model 3
Time (weeks)	0.04* (0.01)		0.01 (0.01)
Usage (lessons)		0.03*** (0.01)	0.03*** (0.01)
y-intercept	0.28*** (0.06)	0.19*** (0.06)	0.16*** (0.06)
adjusted R2	0.03	0.07	0.07
N	411	411	411

*p<.05, **p<.01, ***p<.001, (standard errors in parentheses)

A third model (Model 3) incorporated both Time and Usage as predictors of growth. This analysis allowed us to examine whether growth was predicted by Usage when Time was held constant, and vice-versa. In this way, we were able to test whether the observed growth was just a function of more time to learn independent of product use (e.g., from classroom instruction), or whether growth was associated with using Amplify Fractions. We found that, when both Time and Usage were included, Time was no longer a significant predictor of growth. Usage, on the other hand, was again a significant predictor of growth. Holding Time constant, each lesson completed was associated with additional growth of 0.03 sds (approximately 1.2 percentile points). Note that the coefficient for Usage as estimated by Model 3 is the same as in Model 2, indicating that Time was not a significant influence on the growth associated with Usage. These results provide evidence against the possible alternate explanation for growth, which would say that growth could be a result of the simple passage of time and not usage.

Discussion

This series of analyses tested the theory of action for Amplify Fractions, that is, that students using the product would demonstrate substantial growth in fractions knowledge. Students were assessed using different items on equated pre- and posttest forms. A comparison of Amplify Fractions users' pretest and posttest fractions knowledge showed that they increased, on average, 0.57 sds., which would qualify as a moderate effect size. Further analyses showed that students who used the product the most also had the largest gains (+0.78 sds.). In addition, regression analyses provided evidence against the possible explanation that growth was a result of the simple passage of time between the tests, and provided evidence for the explanation that increased product usage was associated with more growth. Taken together, these results provide promising indications that the product is an effective tool for learning fractions. Further research, comparing additional outcomes for users and similar non-users, would be helpful for isolating the product's causal effects on fractions knowledge and on its effects on improving broader math knowledge as well.

References

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Kim, S. (2006). A comparative study of IRT fixed parameter calibration methods. Journal of Education Measurement, 43, 355–381.

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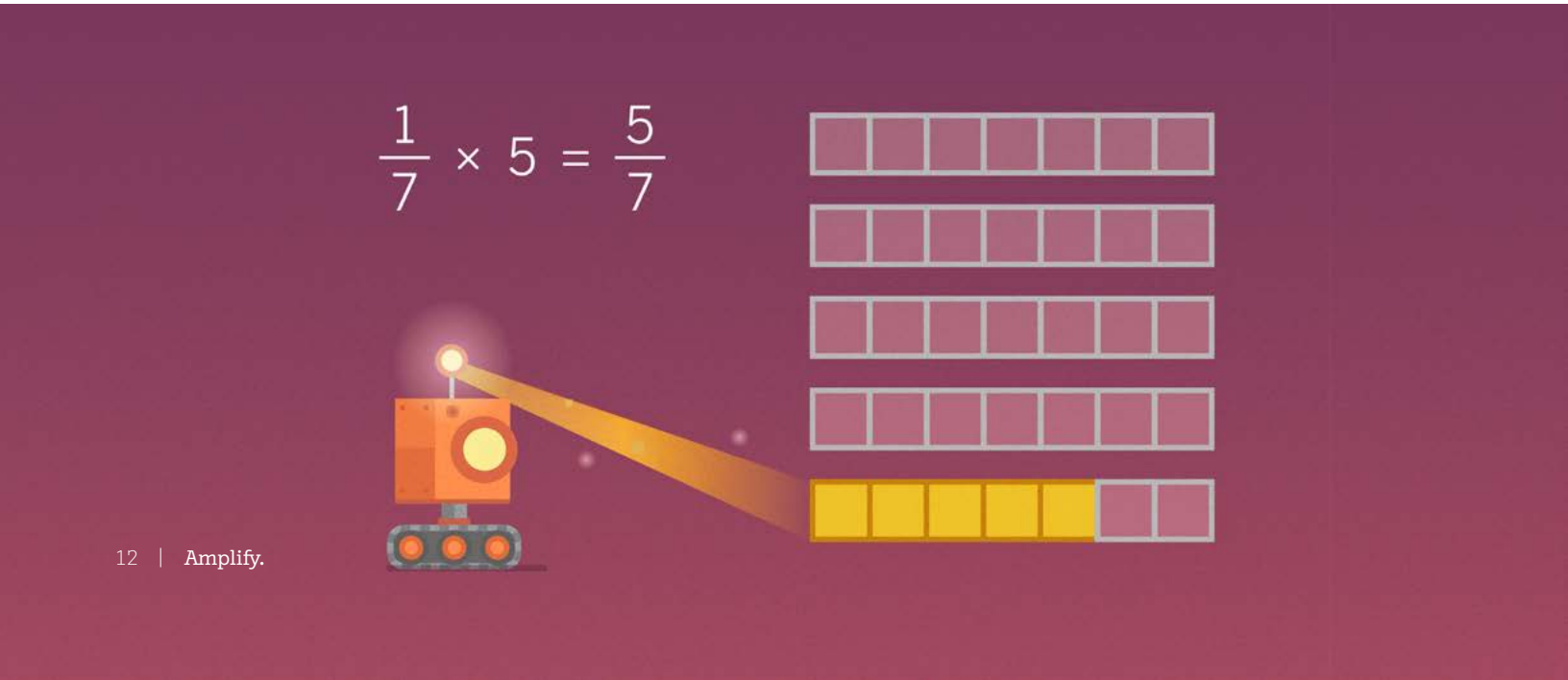
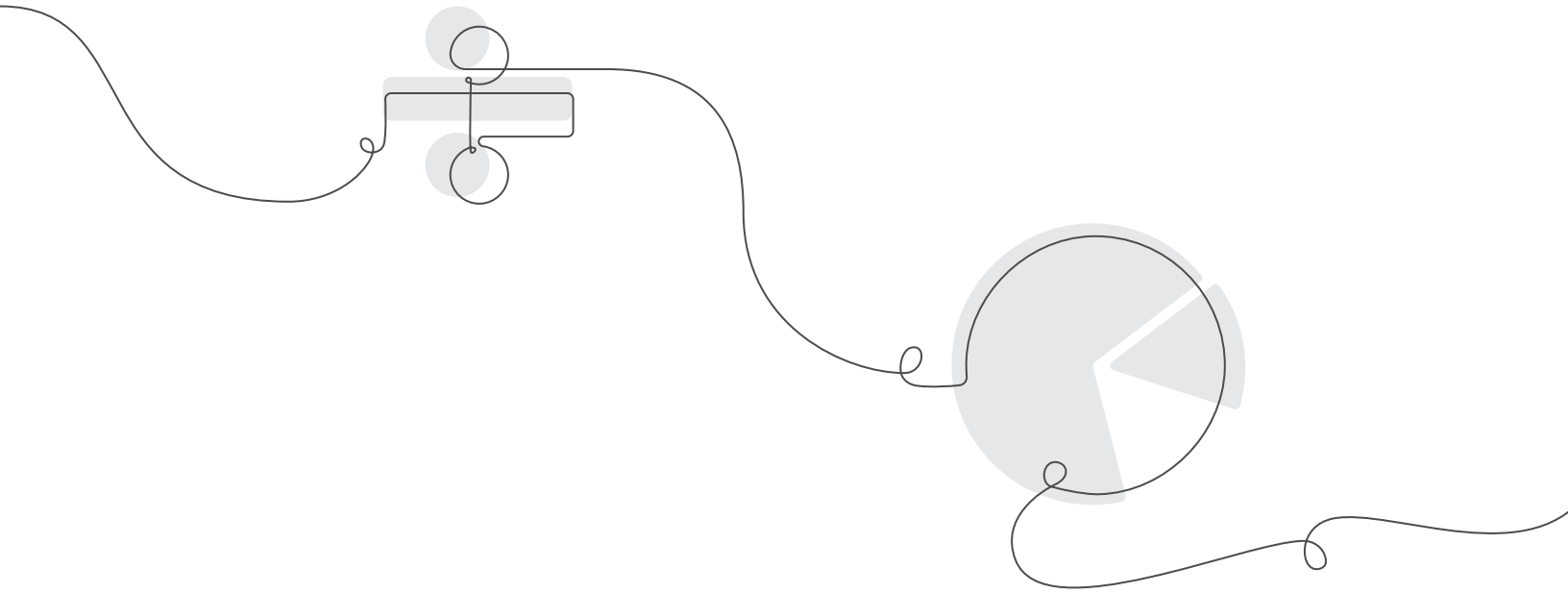


Appendix A: Item statistics

Item	N	% of students answering correctly	Comment
PARC_10003_001_1	205	0.224	
AMPL_10308_006_1	237	0.346	
AMPL_10019_036_1	209	0.359	
AMPL_10480_009_1	236	0.428	
NAEP_10001_001_1	254	0.445	
AMPL_10373_008_1	214	0.467	
AMPL_10236_002_1	254	0.496	
AMPL_10501_017_1	219	0.475	
AMPL_10348_026_1	236	0.517	
AMPL_10425_001_1	237	0.532	
AMPL_10463_013_1	254	0.539	
AMPL_10267_004_1	238	0.525	
AMPL_10175_122_1	227	0.577	
AMPL_10417_011_1	236	0.589	
AMPL_10281_008_1	237	0.586	
PARC_10001_001_1	236	0.631	
AMPL_10539_132_1	229	0.642	
AMPL_10386_002_1	246	0.650	
NAEP_10002_001_1	237	0.629	
AMPL_10174_040_1	240	0.675	
NAEP_10003_001_1	231	0.693	
AMPL_10239_012_1	237	0.713	
AMPL_10317_003_1	254	0.748	
AMPL_10032_034_1	230	0.735	
PARC_10004_001_1	237	0.743	
AMPL_10444_002_1	219	0.799	
AMPL_10494_003_1	219	0.840	
AMPL_10334_094_1	207	0.130	Removed
AMPL_10421_003_1	237	0.852	Removed
AMPL_10433_004_1	219	0.900	Removed

Item fit and difficulty statistics

Item	Outfit	Outfit (t)	Outfit (p)	Infit	Infit (t)	Infit (p)	Difficulty	Difficulty (se)
AMPL_10019_036_1	0.77	-7.55	0.00	0.86	-4.45	0.00	0.64	0.08
AMPL_10032_034_1	1.21	5.07	0.00	1.14	3.35	0.00	-1.39	0.08
AMPL_10174_040_1	1.08	2.14	0.03	1.07	2.08	0.04	-0.89	0.08
AMPL_10175_122_1	0.78	-7.83	0.00	0.85	-5.30	0.00	-0.18	0.07
AMPL_10236_002_1	0.97	-0.86	0.39	0.99	-0.29	0.77	0.07	0.07
AMPL_10239_012_1	0.97	-0.72	0.47	0.98	-0.40	0.69	-1.39	0.08
AMPL_10267_004_1	0.97	-1.11	0.27	0.98	-0.73	0.47	-0.29	0.07
AMPL_10281_008_1	0.98	-0.56	0.57	0.99	-0.15	0.88	-0.75	0.07
AMPL_10308_006_1	1.35	9.31	0.00	1.13	3.74	0.00	0.73	0.07
AMPL_10317_003_1	0.86	-3.38	0.00	0.90	-2.44	0.01	-1.54	0.08
AMPL_10348_026_1	1.06	1.96	0.05	1.02	0.81	0.42	-0.32	0.07
AMPL_10373_008_1	0.99	-0.36	0.72	0.98	-0.72	0.47	0.13	0.07
AMPL_10386_002_1	0.85	-4.76	0.00	0.93	-2.18	0.03	-0.79	0.07
AMPL_10417_011_1	1.10	3.19	0.00	1.07	2.24	0.02	-0.45	0.07
AMPL_10425_001_1	1.04	1.28	0.20	1.03	0.98	0.33	-0.12	0.07
AMPL_10444_002_1	1.01	0.18	0.85	0.95	-0.93	0.35	-1.98	0.09
AMPL_10463_013_1	1.04	1.20	0.23	1.04	1.18	0.24	-0.23	0.07
AMPL_10480_009_1	0.99	-0.28	0.78	1.00	0.01	0.99	0.25	0.07
AMPL_10494_003_1	0.83	-3.45	0.00	0.93	-1.41	0.16	-2.18	0.09
AMPL_10501_017_1	1.14	4.56	0.00	1.07	2.38	0.02	-0.18	0.07
AMPL_10539_132_1	1.04	1.04	0.30	1.05	1.37	0.17	-0.98	0.07
NAEP_10001_001_1	0.83	-6.04	0.00	0.87	-4.41	0.00	0.27	0.07
NAEP_10002_001_1	1.10	2.86	0.00	1.04	1.18	0.24	-0.75	0.07
NAEP_10003_001_1	1.04	1.09	0.28	1.03	0.97	0.33	-1.11	0.08
PARC_10001_001_1	1.15	4.18	0.00	1.07	2.05	0.04	-1.00	0.07
PARC_10003_001_1	1.05	1.29	0.20	0.99	-0.17	0.87	1.27	0.08
PARC_10004_001_1	0.92	-2.07	0.04	0.97	-0.82	0.41	-1.57	0.08



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