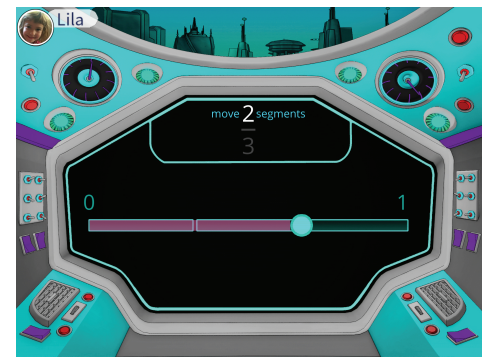
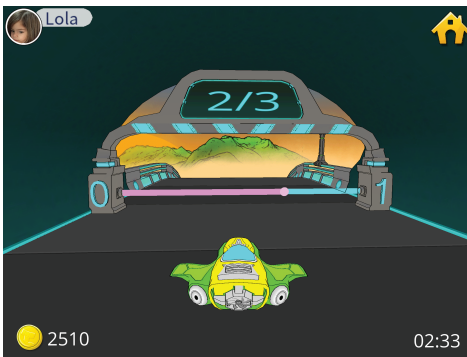


Teachley Fractions is a collection of math games developed under Phase I and Phase II SBIR grants from the National Science Foundation (1519618 and 1632238). The apps encourage conceptual understanding of rational numbers and rational numbers operations for students in grades 3-6. In our first app, **Teachley: Fractions Boost**, students race through a futuristic game world, driving through number line checkpoints and fraction tunnels. This engaging game covers all of 3rd grade fraction standards, including single fractions, comparison and equivalence of fractions.



Research Design

As part of the Phase I research, we conducted a learning study with 17 third through fifth grade students over a period of five weeks during an after school program. The research focused on a prototype of **Boost**, which also covered some 4th grade standards, such as addition and subtraction of fractions with like denominators and fractions greater than 1.

The primary research question in our study on the **Boost prototype** explored the effects of using the software on students' procedural and conceptual knowledge of fractions and fractions operations. To measure students' procedural understanding, we used a number line estimation task. To measure students' conceptual understanding of adding fractions, we designed a semi-structured clinical interview, which was given at posttest.

Students completed a pretest measure at the beginning of week 1, followed by software intervention 1-2 x per week and a posttest measure at the end of the last session. The pretest asked students to estimate the location of a fraction on a number line. There were three types of problems: 1) placing a single fraction on a number line from 0 to 1, 2) placing the sum of 2 fractions on a number line from 0 to 1, and 3) placing the sum of 2 fractions on a number line from 0 to 2. There were a total of 11 items, including 5 items for estimating single fractions, 3 items for estimating the sum from 0 to 1 and 3 items for estimating the sum from 0 to 2. We analyzed each question type for students with a complete pretest and posttest in terms of accuracy (with a margin of error of +/- .1) as well as difference scores between students' values and the correct values. Because we only had two 5th grade student, we grouped the 4th and 5th grade student together.

Results

What are the effects of Teachley Fractions on students' ability to estimate fractions on a number line?

We conducted a repeated measures ANOVA with grade and time (pretest/posttest) as factors on student's precision in estimating single fractions. We found that students were significantly more precise in their estimating at posttest than at pretest, $F(1,13) = 8.35$, $p = .013$ and there was a significant difference between 3rd graders and older students, $F(1,13) = 6.31$, $p = .026$. There was no interaction between grade and time. Additionally, for the latter 2 question types, which asked students to estimate sums of fractions, almost all students performed poorly at pretest and posttest, thus, we do not report this data in detail. We anticipated this finding because few students reached the game levels covering addition and no students saw game levels with a number line from 0 to 2. We conducted research over seven different sessions, but due to inconsistent attendance in the afterschool program, most students completed four or fewer sessions and made less progress in the game than we anticipated.

What are the effects of Teachley Fractions on students' conceptual understanding of fractions?

In the posttest clinical interviews, we asked students to define a fraction and then to estimate where $\frac{3}{4}$ is on a number line and to explain how they figured it out. We followed up by asking what is the meaning of the 4 and the 3 in $\frac{3}{4}$. While students struggled to define a fraction at post test, which is likely due to the difficulty of generalizing one's understanding, a challenging task for children, many students spontaneously used magnitude in their explanations of how they estimated $\frac{3}{4}$. For instance, a third grader accurately placed $\frac{3}{4}$ on the number line and then stated while gesturing 4 invisible line segments, "I counted 4 spaces, then I took away 1 to make 3 and I drove through." Another 4th grader responded, "I went 1,2,3,4 (dividing line into 4 sections with his/her finger) and counted the lines. Go 3." These responses show initial evidence that students began internalizing the magnitude model of fractions and using it to estimate fractions.

Discussion

From our research, we found that students became significantly better at estimating single fractions on a number line after playing our app. Since we conducted the research in the fall, the 3rd grade students had not yet studied fractions in school, and none of the classes had addressed fractions learning so far that academic year. The research was also conducted over a relatively short period of time (5 weeks), so we are confident that the students' gains can be attributed to the gameplay. While we were not able to gather enough information on students' learning from the addition and subtraction components of the prototype, we suspect that upon mastery of single fractions, students would make similar gains in these areas. In general, we found that students struggle tremendously in the area of fractions and there is a great need for expanded content to cover all aspects of fractions learning, including multiplying and dividing fractions, comparing and ordering fractions, estimating fractions greater than 1, and solving for exact answers when operating with fractions.

In response to this study, we expanded our first app, **Teachley: Fractions Boost** to cover all of 3rd grade fraction standards. We also removed any content that addressed 4th grade standards from this app (e.g. addition and subtraction of fractions or fractions > 1). Our second app, **Teachley: Fractions Boost 2**, which is still in development, will cover 4th grade standards in detail in order to give students more game play experience with these challenging topics. Future research planned for the 2017-18 school year will include a randomized control trial comparing **Teachley Fractions** to other fractions software.