Teachley Operations is a suite of math games developed under Phase I and II SBIR grants from the Institute of Education Sciences, ED-IES-12-C-0046 and ED-IES-13-C-0044, designed to promote single-digit operational fluency and strategy development. Children practice facts using powerful visual models of addition and multiplication strategies. Most apps focus on drill with digital worksheets and flashcards. In contrast, Teachley Operations teaches effective math strategies and scaffolds learning to promote conceptual understanding and fact fluency.

Research Design

As part of the Phase II grant, we conducted an initial efficacy study of the games to answer the following research questions: 1) What are the effects of the games on students’ fact fluency and strategy development? 2) How effective is the software for students who struggle in math? We utilized a pre/posttest, between-subjects design. Eighty-three K-4th grade students from two after-school programs in low-income, urban neighborhoods were randomly assigned to either a treatment condition using Teachley’s games or a control condition of other math fact fluency games. Measures included both standardized (STARMath, XtraMath) and researcher-created measures of strategy understanding as well as in-session observations. During the 4-week study, researchers worked with small groups of 5 - 6 students for 10-minute sessions, twice per week. K-2 students played either Teachley: Addimal Adventure or the control software, Pet Bingo, which also addresses single-digit addition, but does not teach strategies. 3rd-4th graders played either Teachley: Mt. Multiplis or Math Evolve, a basic fluency game. Using a turn-taking protocol, researchers observed K-2 students’ strategy vocalizations and explicitly asked 3rd-4th graders about their strategy use.

What are the effects of the Teachley games on students’ fact fluency? To analyze differences in students’ fact fluency, we used a Generalized Linear Mixed Model (GLM) with XtraMath trial data used as a binary dependent variable (memorized or not-memorized) with time, condition, and problem difficulty as factors. We found that students using the Teachley apps improved their fluency more than the control group (F=12.44, p < .001, n = 80).
**Results (con’t)**

*What are the effects of the Teachley games on students’ strategy development?* To evaluate differences in strategy use between the groups, we analyzed session data. In the K-2 classrooms, the prevalence of observable counting on was quite rare (60/920 trials recorded). 80% of the instances of counting on (48 trials) occurred with the Teachley software, but the overall prevalence was so infrequent that the difference was insignificant. In the 3rd-4th grade classrooms, where we explicitly asked students about their strategy use, the strategy differences were much more pronounced. Students using Mt. Multiplis were much more likely to use a sophisticated strategy based on the distributive property ($F = 15.94, p < .001, n=54$). For example, one student using Mt. Multiplis to solve $6 \times 7$ said, “First I did $5 \times 6$ and that gave me 30. Then I put 2 more, which is $2 \times 6 = 12$, so I did $30 + 12 = 42$.” Nineteen of the 21 students using Mt. Multiplis used the distributive property in their explanation at least once during the intervention, whereas only 11 of the 21 students using the control software used this property in their explanations. We also analyzed pre/posttest measures designed to capture students’ strategy use, but did not find differences between the two groups.

*How effective is the software for students who struggle in math?* To examine the effects of the software with struggling learners, we used the STARMath pretest results to identify 1st-4th graders and XtraMath pretest scores for Kindergartners. We found that K-4 struggling learners using the Teachley games improved their fluency more than the control group ($F = 4.61, p = .003, n=33$). We also found that the 3rd-4th grade struggling learners using Teachley were more likely to use the distributive property in the explanations of their strategy use ($F=8.89, p = .003, n = 20$).

**Discussion**

The evidence from this research shows that Teachley apps are more effective than typical fluency games at improving students’ fluency. This result is even more impressive when you consider the fact that students see more equations per session with fluency apps because the strategy tool interactions in Teachley apps take longer. This result may indicate that the number of problems that students see is not as important in improving fluency as giving students tools to encourage efficient strategies for solving problems.

Typically, struggling learners have very persistent difficulties with fact fluency. These students often continue to struggle with basic facts throughout their entire school careers, long after their peers have mastered these facts. Despite this, struggling learners using Teachley apps significantly improved their fact fluency more than those using the fluency-only software.

Future research would benefit from a classroom implementation where the software is integrated within the teaching experience rather than as a separate after-school activity.