



Sokikom Research Study with Scales Technology Academy



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Introduction

President George W. Bush convened the National Mathematics Advisory Panel in April 2006 and this group of scholars, educators, and policy makers reminded nations of its illustrious mathematical past while also providing a stern warning for the future generations:

During most of the 20th century, the United States possessed peerless mathematical prowess—not just as measured by the depth and number of the mathematical specialists who practiced here but also by the extent of mathematical education in its broad population. But without substantial and sustained changes to its educational system, the United States will relinquish its leadership in the 21st century.
(NMAP, 2008)

President Barack Obama continued a focus on improving teaching and learning in the science, technology, engineering, and mathematics (STEM) fields through several initiatives from the White House and the U.S. Department of Education (USDOE, 2015; White House, 2010).

In the modern world, a technically-skilled workforce is critical—not only to compete and survive in the information-based global economy, but also to underpin national leadership and security (Schacht, 2007). But the U.S. is failing to develop this workforce. For decades, the U.S. education pipeline has not produced the necessary number of students for jobs in (STEM) fields—jobs that are outpacing overall job growth by 3:1 (National Science Board, 2008). Some argue that a key factor leading to this is the poor performance of the U.S. mathematics education system. In the past forty years, over a dozen studies show U.S. students consistently score lower in math compared to many other countries (Baldi, 2007; Crosswhite, 1985; Gonzales, 2004; Husen, 1967; Peak, 1997).

President Bush formed the National Mathematics Advisory Panel (NMAP) to understand why U.S. students rank poorly in mathematics. One key finding is a need for more focus on teaching math topics in greater depth during elementary years (NMAP, 2008). The elementary school years are critical in mathematical development as most underlying concepts for mathematics are learned then. Elementary level math introduces students to mathematical concepts that they will use in subsequent math classes and a multitude of other classes—not to mention various other areas throughout their life (Ma, 1999). But what happens when students don't understand these math concepts during the elementary school years? Unfortunately, they generally get left behind as their math deficiencies compound through years of subsequent math classes (NMAP, 2008).

In the current math education system, most teachers use an adopted curriculum such as a textbook and create lesson plans to teach specific topics. Even though teachers care deeply about reaching all their students, it isn't feasible for them to individualize instruction for an entire class. In the current model, most teachers end up providing math instruction and assigning math problem sets to students in a one-size-fits-all manner. Students are expected to develop mastery in math topics through completing these problem sets, in and out of the classroom. This is problematic for many reasons. Teachers generally assign the same set of problems to the entire class, which does not address students' unique needs. Next, problem sets are often abstract and devoid of context. Students can complete these sets without understanding relevance. Furthermore, problem sets suffer from delayed feedback, as students generally don't find out which mistakes they've made until one or more classes later. While students may care deeply as they grapple with their homework, by the time they get it back, the learning moment

has often passed. Finally, problem sets under-utilize group learning even though recent research documents that social and intellectual support from peers and teachers is associated with higher mathematics performance for all students (NMAP, 2008). If these problems are left untreated during the elementary school years, they are likely to lead to poor student performance in math standards and development of anti-math attitudes in later schooling and life (Loveless, 2003). This has resulted in a much larger problem—the U.S is not producing enough technically skilled workers (National Science Board, 2008). Consequently, this may jeopardize not only the U.S. economy, but also national leadership and security (Schacht, 2007).

There is substantial research to support the hypothesis that games can help address many of these deficiencies at once (Eck, 2006; Prensky, 2001; Randel, 1992; Shaffer, 2005). This empirical research includes meta-analysis of the instructional effectiveness of games compared to conventional classroom instruction. This research has consistently found that games promote learning across multiple disciplines and ages. Research also shows that playing educational video games improves student motivation to learn mathematics (Rosas, 2002). Improved student motivation to learn math has been further shown to result in improved mathematical performance (Cordova, 1996; Gottfried, 1990; Schiefele, 1995; Viljaranta, 2008).

But math games for elementary school students have existed for many years. Why haven't they improved the effectiveness of mathematical learning? Before answering this, it is imperative to understand the elements a math game should possess, if it is to improve the way elementary school students learn math. An effective math game needs to be able to: (1) encapsulate the math in contexts that engage and motivate students; (2) give students the ability to try different approaches to challenges in an environment that minimize the significance of errors, and rewards exploration and discovery; (3) present math challenges that adapt to the learning level for each player; (4) facilitate and encourage individual and communal learning through multi-student interactions, and (5) provide immediate feedback to players on problems and track players' progress over time.

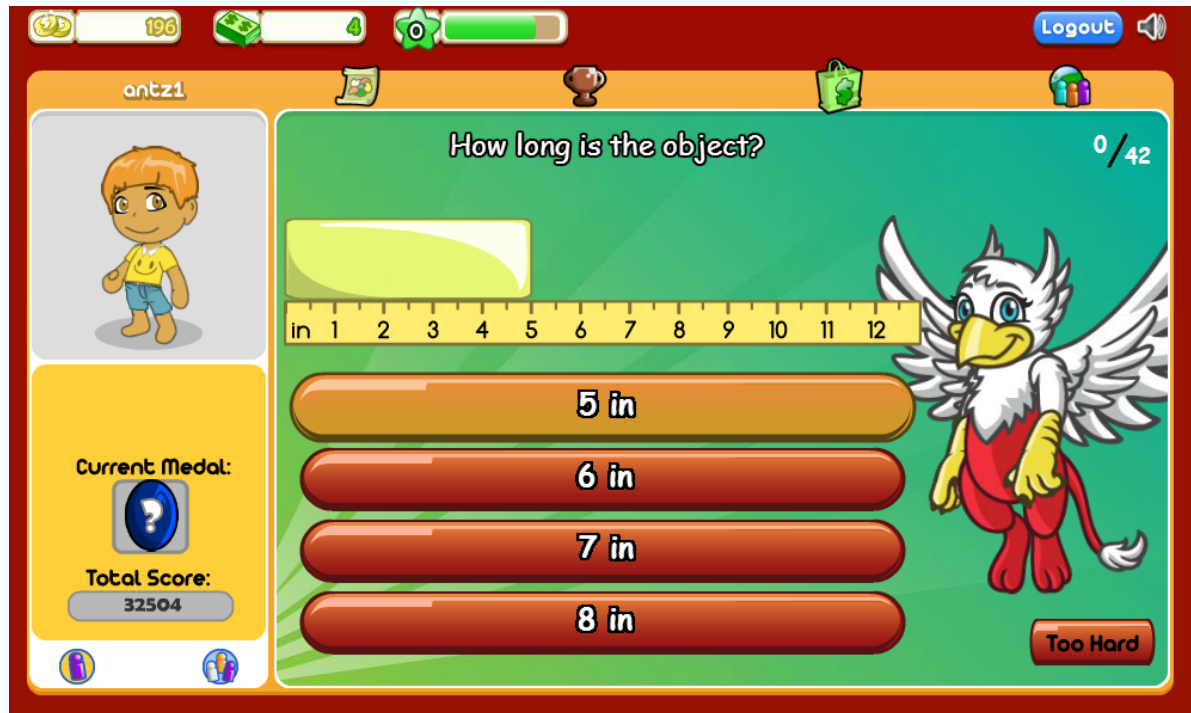
Sokikom has synthesized these needs to develop a new approach for learning in games—through Exploration, Discovery, Application, and Practice (EDAP). EDAP is underpinned by the constructivist learning theory (Merrill, 1991; Piaget, 1967) and sub theories of guided discovery learning (Bruner, 1961; Mayer, 2004) and situated learning (Lave & Wenger, 1991), as well as research on the way elementary school students learn math (Baroody, 1989; Bitter, 1994; Bitter, 2008a; Bitter, 2008b; Isaacs, 2001). Initially funded through three SBIR grants (<http://ies.ed.gov/sbir/sokikom.asp>) from the Institute of Education Sciences (IES)—a research entity within the U.S. Department of Education—Sokikom developed numerous games that focus on four mathematical domains aligning with the Common Core standards:

- Fractions
- Operations & Algebra
- Measurement & Data
- Geometry



A Look At The Program

Pre-test



Features:

- Students start Sokikom by taking a pre-test containing standardized questions in whichever mathematical domain they choose to begin. An example pre-test question for the Measurement & Data domain is shown above.
- Questions start off at a grade K-1 level and then progressively become more difficult as students answer questions correctly. If a student has gaps in a series of related questions, the system will exit the pre-test and place the student at the correct starting point to begin individualized and self-paced learning.

Interactive Content



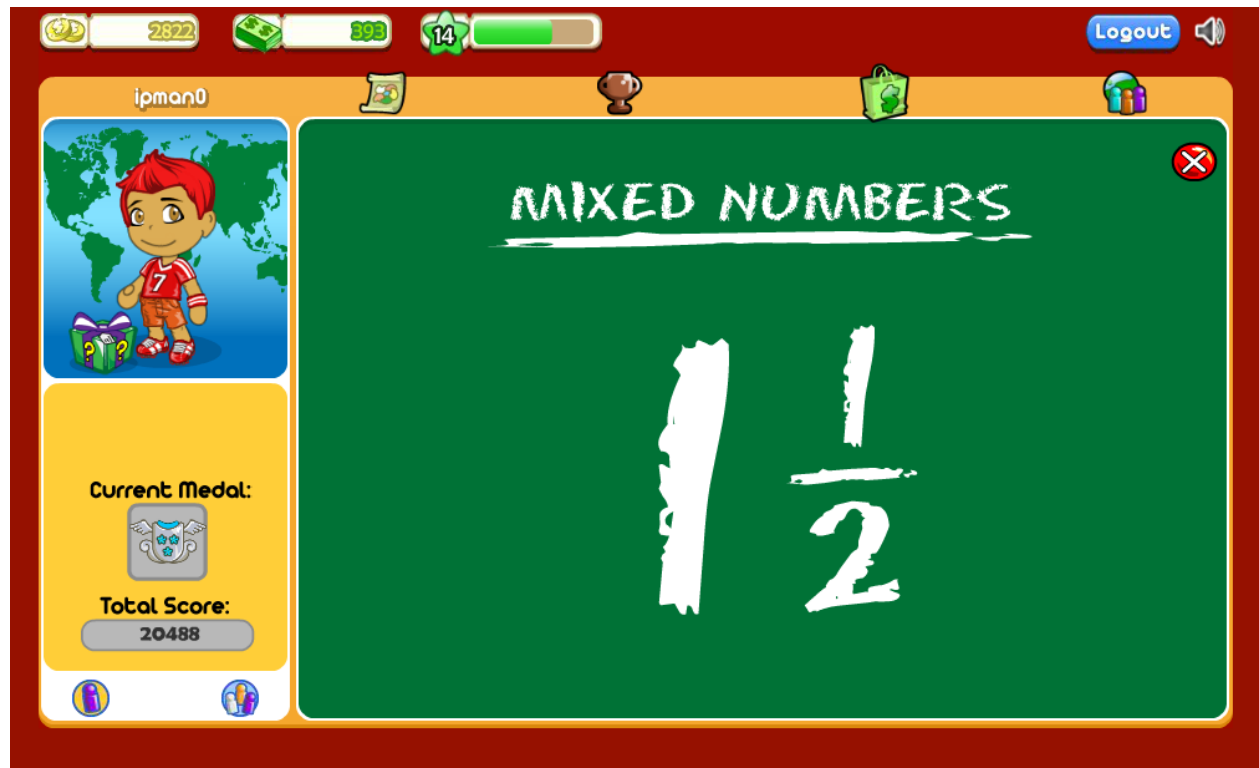
Features

- Sokikom games contain experiential activities that provide students with contextually meaningful learning that is highly visual and interactive.
- In the example above, students are able to freely manipulate whole blocks by splitting them into smaller denominations—eighths, fourths, or halves. Then students can combine those quantities in any fashion to produce larger amounts.

Research

The situated learning theory posits that learning is embedded within activity and presented in meaningful contexts through relevant applications (Lave & Wenger, 1991). Studies have shown that students' learning from application-based mathematics curriculum score higher on math standards than students in other curricula (Isaacs, 2001). At the same time, the discovery learning theory uses inquiry-based learning where the learner draws on his or her past experiences to discover facts and relationships in new domains. Students interact in the new domain by freely exploring and experimenting to develop a better sense of the rules. As a result, students may be more likely to remember concepts and knowledge discovered on their own (Bruner, 1961).

Instructional Scaffolding and Pedagogy



Features

- Sokikom uses a guided discovery learning model by offering students instructional scaffolding including videos as shown in the example above.
- If students become stuck on a question they can receive a hint as shown in the bottom left. After answering incorrectly two times in a row, students are shown one way to solve an answer—shown in the bottom right.

Research

Guided discovery has been proven to be more effective than pure discovery in promoting learning and transfer (Mayer, 2004).



Social Learning



Features

- In addition to independent practice, Sokikom allows students to play team-based multiplayer games where students collaborate and compete in real-time to solve math problems. All interaction takes place in a safe and secure environment.
- A single multiplayer game can be played among 2 to 32 students at the same time. There can be an unlimited number of multiplayer games being played at any given time.
- In the example above, students are playing an Operations domain multiplayer game to develop arithmetic fact fluency. Students must solve an individualized arithmetic question and are rewarded if they help their fellow teammates solve their questions.
- These features are unique to Sokikom and unlike anything currently available.

Research

The situated and social learning theories posit that social interaction and collaboration are essential components of learning (Lave & Wenger, 1991). Furthermore, recent research documents that social and intellectual support from peers and teachers is associated with higher mathematics performance for all students (NMAP, 2008).

Common Core Mastery Reports

Back

Overall Mastery → Grade 3 → 3.NF.3

Standard 3.NF.3 - Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size.

a) Understand two fractions as equivalent (equal) if they are...

3 Sokikom levels assess mastery & 2 Sokikom levels are extra practice for this standard

Student	Fractions Level 03 Extra Practice	Fractions Level 04 Extra Practice	Fractions Level 05 Mastery	Fractions Level 11 Mastery	Fractions Level 21 Mastery
Alexis Romero	100 (PT)	100 (PT)	100 (PT)	100 (PT)	
Amrita Sangani	100	100	94	100 (PT)	
Brock Johnston					
CJ Mara					
Devon P.	100 (PT)	100 (PT)	100 (PT)	100 (PT)	100 (PT)
Divya Gupta	85	80	73		
Ethan Griifin	100	100	94		
Giovanni Lopez	100	100			
Haley Scull	100	100	100 (PT)	100 (PT)	35
Ishita Sood	100 (PT)	100 (PT)	100 (PT)	100 (PT)	
Mitchell Septoff	100	100	100	100	88
Ryan Abe	100	100	100 (PT)	100 (PT)	
Ryan Morokutti	100 (PT)	100 (PT)	100 (PT)	100 (PT)	100 (PT)
Seaden Crowley	92	100	89		

Color Key:

MASTERED

APPROACHING

REMEDIAL

YET TO PLAY

Hide %

PT = Placement Test

Help & Wishlist

Features

- Sokikom includes in-depth Common Core Mastery Reports that allow teachers to understand how their classroom is performing on each state standard.
- In the example report shown above, a teacher can view a classroom's performance on Common Core Standard 3.NF.3, along with seeing the various Sokikom game levels that provide practice or mastery in that standard.
- Teachers can also view how their students are performing across grades K-6 in related standards as shown in the bottom.

Student	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Aidan Gamez						
Audrey Ackerman						
Audrey Sjoberg						
Beau Roth						
blake rovek						
bridgette campbell						
Caroline Horton						
cole bergstrom						
cristina lozano						
david crouch						
Gianna Finear						
Hayley Skonieczny						
jack kirsch						
Julia Jenkins						
Katharine Caston						
Katharine Caston						

Color Key: **ON TRACK** **MASTERED** **APPROACHING** **REMEDIAL** **YET TO PLAY** [Help & Wishlist](#)

Features

- In addition to all-class progress reports, Sokikom includes in-depth individual reporting features that allow teachers to sort based on performance, work on standard clusters, or when levels were completed. An example individual report is shown below.

[Back](#)
[Overall Mastery](#) → **Individual**

Select another student: Caroline Horton

Caroline Horton's Individual Report

Date Played	Game Level Played	Common Core Standards	Learning Objective	Performance
Jun 07, 2013 1:50 PM	Geometry Challenge 1	Multiple	Select the correct angle based on the value or property displayed. (Time-based)	65% in 106 sec
Jun 07, 2013 1:47 PM	Geometry Challenge 2	Multiple	Draw a line of symmetry on a displayed shape (Time-based)	88% in 117 sec
Apr 28, 2013 7:12 PM	Measurement Level 34	5.MD.1	Convert among mass units of measurement and Use these conversions in solving problems.	91 %
Apr 28, 2013 7:03 PM	Fractions Level 39	5.NF.7	Divide with large improper fractions.	90 %
Feb 12, 2013 10:51 PM	Fractions Level 02	3.NF.1	Create representations of fourths.	100 %
Feb 12, 2013 10:49 PM	Geometry Level 03	1.G.1	Build and draw shapes to possess defining attributes.	100 %
Feb 12, 2013 10:47 PM	Geometry Level 04	2.NBT.2	Locate a number with 100 on a number line.	100 %
Feb 12, 2013 10:45	Geometry Level 05	2.NBT.2	Locate a number with 100 on a number line.	100 %

- Teachers are also able to see all data embedded in program assessment, including the exact questions students are missing, how much time was taken to complete the questions, and if students sought aid to solve the problem (see example below).

[Back](#)
[Overall Mastery](#) → [Individual](#) → **Operations Level 30**

Benjamin Franklin

75 %

Play Level

[See image for this level](#)

Objective: Divide two-digits with or without regrouping.

Question	Solution	Student's 1st try	Student's 2nd try	Time taken (11:04)
$77 \div 6 = ?$	12R5	12R5		<div></div> 1:07
$95 \div 2 = ?$	47R1	47R1		<div></div> 1:28
$75 \div 5 = ?$	15	15		<div></div> 1:46
$48 \div 3 = ?$	16	16		<div></div> 2:02
$57 \div 4 = ?$	14R1	16R1	16R3	<div></div> 1:22
$48 \div 3 = ?$	16	16		<div></div> 1:39
$90 \div 7 = ?$	12R6	11		<div></div> 1:40

Color Key:

CORRECT

SELF CORRECT

INCORRECT

Help & Wishlist

Research Questions

The purpose of this study is to investigate the impact on elementary student learning outcomes and motivation from using two different versions of Sokikom – one with instructional scaffolding (*latest version*), and one without.

The major research questions being addressed in this study are:

- *What effect does using Sokikom have on learning outcomes and student motivation for each version?*
- *What are the differences, if any, on the length of time students voluntarily play Sokikom outside of class?*

We hypothesize that the combination of the affordances that are inherent to video game environments and the benefits of social play and individualization, will have an effect on math learning outcomes and student motivation.

Procedures

Sample

Researchers from Arizona State University and Sokikom conducted a study in the fall of 2010 in order to investigate this hypothesis. Seven classrooms participated in the study. Two classrooms from third, fourth, and fifth grade and one classroom from a combined fourth/fifth grade class. Altogether, there were 164 participants in this study. Out of those, 134 completed the entire study. The participants were enrolled in grades 3, 4, and 5 at Scales Technology Academy located in Tempe, Arizona. This grade range was selected because students are introduced-to and learning fractions during these years.

School Profile

- Scales Technology Academy
- K-5 school with a student population of 489.
- 80% are eligible for free-and-reduced lunch.
- 84% minority population
- 1 to 1 Macbooks

Measures

Student learning outcomes were measured using an online mathematics standards test designed to assess students' fractional knowledge. Students' motivation to learn math from playing the game will be measured by the amount of voluntary time-on-task.

Mathematics standards test:

Student performance in the fraction specific math standards covered in Frachine will be tested using a math standards test developed by Sokikom. The questions in this test will be similar to those found in the Arizona Instrument To Measure Standards (AIMS). All questions on the AIMS are evaluated by committees of content experts to ensure their appropriateness for measuring standards and fairness to gender, ethnicity, and language. Our team has found these questions to be similar to corresponding tests in several other states.



Intrinsic Motivation measured by voluntary time-on-task.

Motivation is being measured by the amount of voluntary time on task that students choose to use the game outside of class. For the purpose of this study, we believe the amount of time, if any, students choose to play the game outside of the regularly scheduled study time, is an indication of their interest.

In a prior study, our research team used The Children's Academic Intrinsic Motivation inventory (CAIMI) to measure motivation. The CAIMI was developed by Gottfried in 1985. CAIMI has been used in several related studies due to its validity, applicability, and reliability—including a study that revealed that intrinsic math motivation was found to be related to initial and later levels of math achievement (Gottfried, 1990). However, these studies along with our prior findings, indicate the CAIMI is more appropriate for longer studies lasting at least 3 months (Gottfried, 1990; Gottfried, 2007). Therefore, we will not be administering the CAIMI for this study.

Study

Students played one of Sokikom's web-based games that teaches fractions ("The Fraction Game"). The Fraction Game uses constructivist learning theory techniques to teach and give practice in Fraction concepts for elementary students. A new version of The Fraction Game has been created by adding individualized instructional content, i.e scaffolding. The scaffolding is designed to improve learning and motivation. The purpose of this study is to determine the impact of playing both versions of The Fraction Game on student math learning outcomes and motivation.

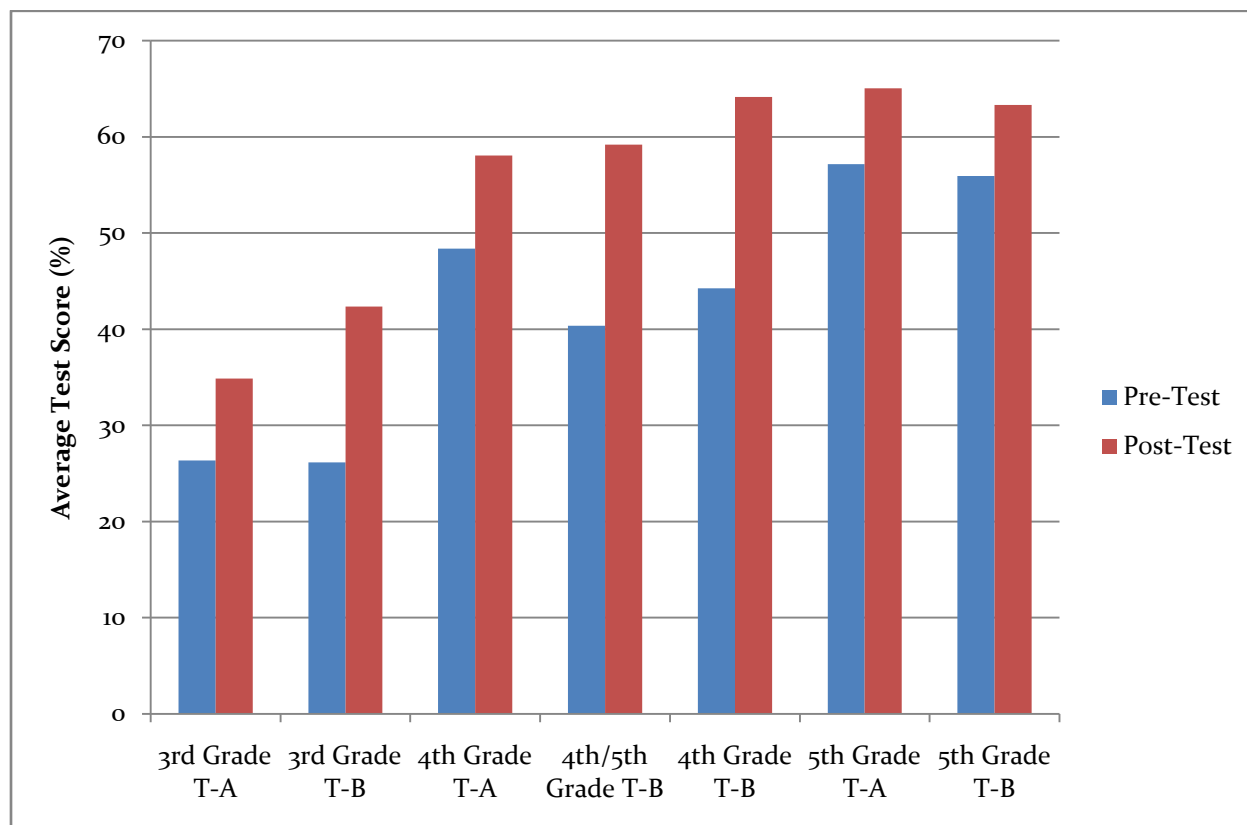
Our team worked with teachers from the school prior to the study, to familiarize them with the game and study procedures. Students were given parent permission forms to participate in the study. The pilot study involved seven classrooms, $n = 164$, from grades 3, 4, and 5. Three of the classes were randomly selected to serve as the treatment-A group and play the base version of The Fraction Game. The remaining four classes served as the treatment-B group and played The Fraction Game *with Scaffolding*. One of the classes in the treatment-B group was a mixed 4th and 5th grade ELL class. Both groups played their respective game for 20 minutes a day, for eight days. We started day one of the study by administering a summative pre-test for all students using the math instrument described earlier. During the experiment, we collected observational and self-report data from students to assess implementation fidelity for student engagement and usability. Observational and self-report data was also collected from the teacher to determine how easy both interventions were to use and incorporate into classroom practice. Our servers have stored the amount of time that students spent on the game in and out of the classroom. On the last day of the study, all students were given a summative post-test using the math instrument from the pre-test. Results of both groups were analyzed for effects on student outcomes using multiple regression analysis and a paired samples T-test.

Results

Of the 164 students that started the study, 132 completed it by taking the post test. The breakdown of the number of participants in each group is shown in the table below. Note that “T-A” refers to the Treatment-A classes that used the basic fractions game and “T-B” refers to the Treatment-B classes that used the fractions game with instructional scaffolding.

<i>Class</i>	<i># Students taking pre-test</i>	<i># Students taking post-test</i>
3rd Grade T-A	21	17
3rd Grade T-B	18	14
4th Grade T-A	26	22
4th/5th Grade T-B	24	22
4th Grade T-B	26	21
5th Grade T-A	25	20
5th Grade T-B	24	16
TOTAL	164	132

Pre-Test vs. Post-Test for Both groups



*Observations: Post-test scores are higher for all grades and classes in both groups. **Treatment B classes showed the most improvement.***

t-test

We conducted a paired-samples *t*-test to determine whether there was a significant difference between pre- and post-test mathematics performance of participants after spending time with Sokikom. This test was done inclusively of both the treatment-A and treatment-B groups. The results indicated that the mean for the post-test ($M = 56.07$, $SD = 20.78$) was significantly greater than the mean for the pre-test ($M = 43.71$, $SD = 19.51$), $t(134) = 7.31$, $p < .01$. The standardized effect size index, d , was .29. Looking individually at the mean differences for both the treatment-A and treatment-B groups reveals that the treatment-A mean score increased by 8.75% and the treatment-B group mean score increased by 14.96%.

Anova

A one way analysis of variance (ANOVA) was conducted to evaluate the impact of adding individualized instructional content, i.e. scaffolding to Sokikom. The independent variable, the scaffolding of instruction within the game, included two levels, scaffolding and non-scaffolding versions of the game. The dependent variable was the change in scores on the mathematics standards test taken prior to time spent in the game environment and after time spent in the

game environment. Although there was a mean improvement, The ANOVA was non-significant, $F(1, 106) = 2.92, p = 0.09$.

A 3 x 2 ANOVA was conducted to evaluate the effects of the two versions of the game and grade level on the change in scores on the mathematics standards test from pre-test to post-test. The means and standard deviations for the change in mathematics standards test scores as a function of the two versions of the game are presented in Table 1. The ANOVA indicated no significant interaction between the versions of the game the students played and their grade level, $F(2, 102) = .82, p = .44$, partial eta squared .02. No significant effects were observed for grade level or for the version of the game that participants played. This may be due to the small sample sizes used for each grade group and the unanticipated drop-off that occurred from many enlisted students not completing the study, e.g. third grade treatment-B group had 14 students and fourth grade treatment-A class had 22 students.

Table 1 - Means and Standard Deviation for Differences in Scores on Mathematics Standards Test

Grade	Game Version	Mean	SD
3	Treatment – B	17.42	5.67
	Treatment – A	8.53	4.75
4	Treatment – B	19.91	4.27
	Treatment – A	9.68	4.17
4, 5 combo	Treatment – B	18.81	4.29
5	Treatment – B	7.38	4.89
	Treatment – A	7.90	4.38

Table 2 - Tests of Between-Subjects Effects

Dependent Variable: PrePostDiff

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1116.512 ^a	1	1116.512	2.916	.091	.027
Intercept	15354.290	1	15354.290	40.104	.000	.274
Condition	1116.512	1	1116.512	2.916	.091	.027
Error	40583.146	106	382.860			
Total	56423.000	108				
Corrected Total	41699.657	107				

a. R Squared = .027 (Adjusted R Squared = .018)

Student Voluntary Time Spent Playing Outside of Class

Voluntary time students spend is defined as anytime outside of a one hour window before or after the 30 minutes each group was given during the study. The Average of both groups in the table 1 below shows that **90%** of students that used Sokikom voluntarily logged in to play the game outside of scheduled instructional time. These students averaged **1.5 hours** of voluntary game-play time during the course of the study. We determined which students played voluntarily by looking at the student logins that occurred outside of scheduled time (as described above)

Note: this does not take into account whether students actually had computer and internet access outside of school. This question would be useful to ask in a future study. Therefore, it is likely that the effective voluntary play rate would be higher when looking only at students with the means to play outside of class.

Table 1 – Average voluntary students and time for both groups

Average (both groups)	
Number of Students completing Study	132
Number of Students Playing Outside Scheduled Time	119
Percent playing voluntarily	90%
Time (hours)	1.5

Table 2 below show all voluntary students by group. We see that **100%** of the treatment-B group students played voluntarily, which is higher than the **78%** of the treatment-A group. In addition, the treatment-B classes spent considerably more time playing the game averaging **113 minutes** per student compared to the treatment-A classes, which averaged **54 minutes** per student.

Table 2 – Average voluntary students and time for each group

Average for each group	Treatment-A	Treatment-B
Number of Students completing Study	59	73
Number of Students Playing Outside Scheduled Time	46	73
Percent playing voluntarily	78%	100%
Time (minutes)	54	113

Conclusion

The present study illustrates the potential for game-based supplemental math programs to improve student learning. Specifically, this study suggests students' use of Sokikom's Common Core Math Program with instructional scaffolding holds moderate and positive effects on (1) math test scores, and (2) intrinsic motivation to learn math. Sokikom's impact on these two areas is important as the nation increases the rigorous of standards for student learning through the Common Core. This evidence demonstrating students' ability to improve their math learning through a game-based approach while also improving students' motivation towards learning math warrants further study to determine whether there is an interaction between the increases in motivation and the increases in student learning. Similar studies with larger sample sizes should be conducted to validate and replicate these findings across various student populations. It would also be useful to know whether there is differential impact on student learning across English Language Development levels, socioeconomic status, and other variables. Future studies should also investigate the impacts of Sokikom use on student performance in additional measures, like the Smarter Balanced Assessment and the Partnership for Assessment of Readiness for College and Career.

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