Using Math Apps for Improving Student Learning: An Exploratory Study in an Inclusive Fourth Grade Classroom

By Meilan Zhang, Robert P. Trussell, Benjamin Gallegos, and Rasmiyeh R. Asam,
University of Texas at El Paso

Abstract

Recent years have seen a quick expansion of tablet computers in households and schools. One of the educational affordances of tablet computers is using math apps to engage students in mathematics learning. However, given the short history of the mobile devices, little research exists on the effectiveness of math apps, particularly for struggling students. To fill in the gap, an exploratory study was conducted in an inclusive fourth grade classroom, in which about half of the students were either at-risk or had disabilities. The students used three math apps that employed different scaffolding strategies to support learning of decimals and multiplication. Pre- and post-tests showed that use of the math apps improved student learning in mathematics and reduced the achievement gap between struggling students and typical students. More studies should be conducted to identify effective math apps.

Keywords: Elementary school mathematics, Math Apps, Tablet Computers, Number Operations

Many elementary school students struggle with acquiring basic math skills. According to the National Assessment of Educational Progress in the United States, 59% of fourth grade students performed below the level of proficiency in mathematics, and only 8% of students achieved the advanced level (National Center for Education Statistics, 2013). The poor math performance was also reported in math education research. One striking example is that fewer than 10% of students in grades 1-6 were able to solve the math problem (8+4=?+5) correctly (Carpenter, Levi, Berman, & Pligge, 2005).

Educational technology has long been recognized as a valuable approach to improving the mathematics achievement of elementary school children (Chang, Yuan, Lee, Chen, & Huang, 2013; Pilli & Aksu, 2013). According to the National Council of Teachers of Mathematics (2000), "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 11). In the last three decades, various types of computer-assisted math programs have been developed and studied. Recent reviews on educational technology for math learning reported a general positive effect on students' math achievement (Cheung & Slavin, 2013; Li & Ma, 2010; Slavin & Lake, 2008).

Recent development of tablet computers offers new potential for math learning. Compared to desktop and laptop computers, tablets are light and portable. For example, the iPad weighs 1.44 pounds and the iPad mini weighs only 0.68 pound. Most tablets have a long battery life that can last an entire school day without recharge. A fully charged iPad can be used for 10 hours. The light weight and long battery life allows students to use tablets for an extended period of time across settings. In addition, touch screen is easier to use than mouse and keyboard, and offers a better sensory experience to children by direct touch and physical movement (Paek, Saravanos, & Black, 2012). Segal (2011) found that children who used a touch-screen tablet performed better in arithmetic and numerical estimation than children who used a mouse input. Geist (2012) observed that two-year old toddlers were able to use iPads with little direction from adults.

In recent years, apps—software applications that run on tablets and smartphones—have grown rapidly. Apple opened the App Store in July 2008 with 500 apps for iOS devices (Apple Press, 2013). Google Play, formally known as Android Market, was introduced in October 2008 with 167 apps for Android devices (Hill, 2008). Now there are over one million apps in both online stores.1 Moreover, an abundant amount of math apps are available in both the App Store and Google Play. In this study we focused on math apps for decimals and multiplication because both are essential concepts for mathematical competence at the elementary grades and beyond (Rathouz, 2011; Steckroth, 2010). They are key concepts emphasized in the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010). They are also the concepts that students with special needs and learning disabilities struggle with (Zisimopoulos, 2010).

Math apps that run on portable tablets offer great affordances for math learning (Segal, 2011). First, it allows learners to work on math problems at their own pace, which can be particularly useful for struggling students who need more time to solve a problem (Baker, Gersten, & Lee, 2002). Math apps can also provide immediate feedback to individual learners about their performance, which would otherwise be difficult to achieve during general instruction. Providing feedback to students in a timely manner is important for learning, especially for special education students (Baker, et al., 2002; Hattie & Timperley, 2007). Yeh (2010) found that providing rapid feedback to students about their performance is the most cost-effective approach for raising student achievement than a longer school day, increase in teacher salary, and class size reduction. Brosvic and colleagues (2006) found that students with math learning disabilities benefited from immediate feedback to their performance, but not from delayed feedback. In sum, the capability of providing immediate feedback to students through math apps on portable devices is promising.

Figure 1: Splash Math screenshot

For example, Splash Math (StudyPad, 2012) is a comprehensive math app that allows students to work on math problems at their own pace, and provides immediate feedback to the correctness of student answer. It includes over 140 worksheets on addition, subtraction, multiplication, division, decimals, fraction, measurement, and geometry. Each category includes several sets of problems. Figure 1 shows a problem in Splash Math about place values of decimals. This app makes it easy for teachers to give clear instruction to students, for example, "Practice problem set 4 until you get at least 20 out of 24 questions correct." Splash Math also tracks student progress and provides a summary of student performance.

In addition, number lines are often used in math education to make abstract numbers such as integers, decimals, and fractions more meaningful and comprehensible to students (Saxe, 2012). Representing numbers on a number line is an important skill that involves

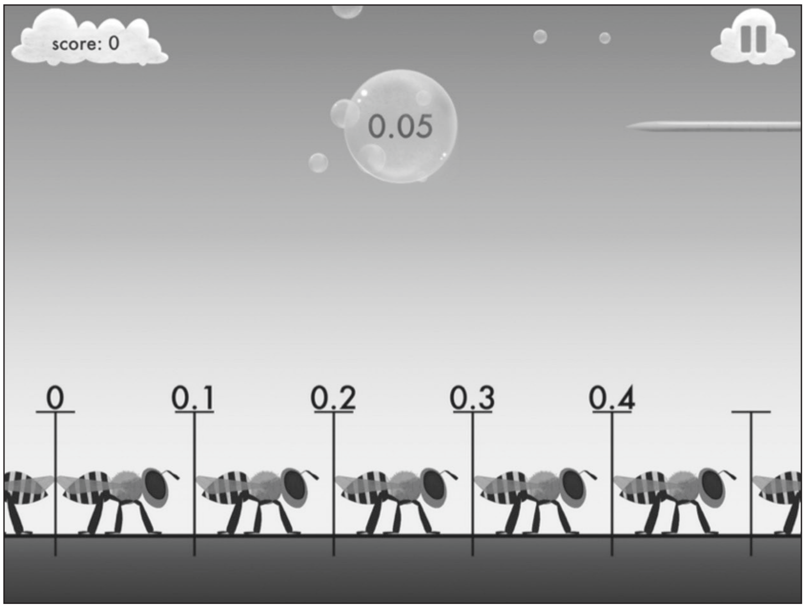

Figure 2: Motion Math Zoom screenshot.

understanding of order, unit, interval, and scale. Martinie (2013) found that middle school students still had difficulty placing 0.6 and 0.06 correctly on a number line. Physical number lines with fixed color, shape, interval, and scale may sometimes introduce misconceptions to students. For example, students may believe that number lines should have certain color or line weight (Kirby, 2013).

Motion Math Zoom (Motion Math, 2012) is one example of what Kirby (2013) called "idealized number line." Motion Math Zoom allows students to place numbers on an interactive number line, whose units, intervals, and scales are changeable. Students can zoom in, zoom out, and move the number line to find the right place

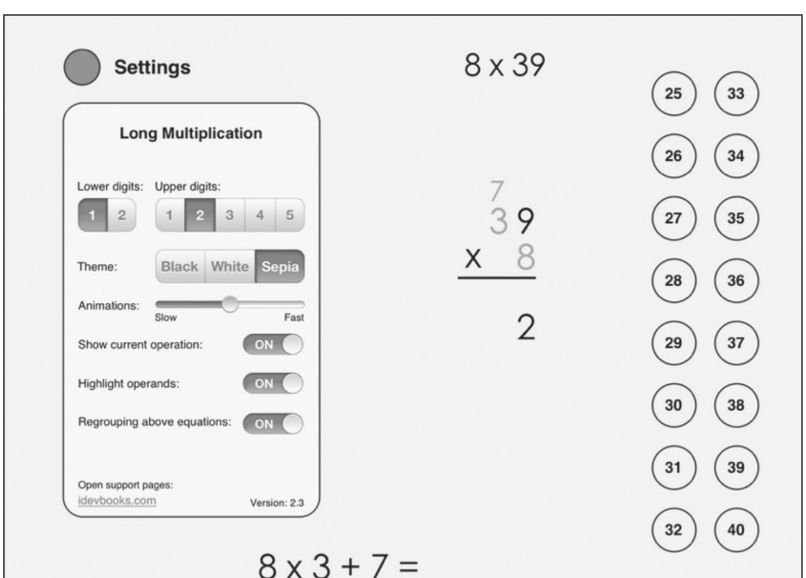

Figure 3: Long Multiplication screenshot.

for a number shown in a bubble on the screen. Students can increase the challenge by turning on the needle option. In that case, they need to place a number to the correct spot on the number line before the needle pops the bubble. This app includes different levels ranging from integers from 1 to 1,000, negatives, and decimals in tenths, hundredths, and thousandths. Figure 2 shows a screen on decimals in hundredths.

Mathematical computation and problem solving often involves complex rules and procedures, which can be challenging for many students (Barringer, Pohlman, & Robinson, 2010). When working with multiple-digit multiplication, for example, students must remember and follow the correct sequence, and align numbers in space correctly to do the calculation. One scaffolding strategy to support student learning is breaking down complex procedures into smaller, manageable steps (Vaughn, Wanzek, Murray, & Roberts, 2012). For example, multiple-digit multiplication includes repeating sequences of single-digit multiplication and addition.

One such app is called Long Multiplication (iDevBooks, 2012), which breaks down a multiple-digit multiplication problem into smaller steps and allows students to solve the problem step by step. This way, the implicit steps to solve a multiplication problem are made explicit to students. In each step, if students enter a correct answer, the answer will fly to the right place. Otherwise the answer will stay in the same place, indicating that their answer is wrong. This app allows users to set the multiplicand to have up to 5 digits and the multiplier to be 1 or 2 digits. Figure 3 shows a screenshot on a two-digit by one-digit multiplication problem.

Given the short history of mobile touch screen devices, research on math apps is still in its infancy (Peluso, 2012). This study aimed to examine this research question: Can selected math apps improve student learning of math, particularly for struggling students?

Method

Setting

This study took place in a fourth grade classroom at a public elementary school in an urban city in the southwestern United States. This school enrolled about 800 students, among which over 90% were Hispanic, and 68% were eligible for discounted or free lunch. The teacher was a Hispanic male and had five years of teaching experience. Each student was supplied an iPad with the math apps. Prior to this study, the students did not have much experience using iPads in school.

Participants

Eighteen fourth grade students from the same classroom participated in this study, including 7 girls and 11 boys. Seventeen students were Hispanic and one was African American. Four students were identified with at least one disability, including autism, emotional disorder, dyslexia, and learning disability. Six students were identified as at-risk students who received additional service in school due to problematic behaviors or inadequate academic progress. Seven students were not identified with any condition and there was one gifted student. The average age of the participants was 9 years.

Procedures

The students used Splash Math, Motion Math Zoom, and Long Multiplication in four math class sessions over the course of one month, each session lasting about 80-90 minutes. The students had learned the concepts of decimals and multiplication prior to using the math apps. These apps were used to supplement regular instruction. In each class session, the teacher or the first author spent 5-10 minutes teaching the students how to use the apps. When students were using the apps, the teacher and the first author provided help to students who had problem with the math tasks. The students worked individually on the math apps, but they could talk to their neighbors.

In the first session, the students spent about 40 minutes using Splash Math. They were asked to solve the first four problem sets in the decimals section, each set including 24 questions. They were told to pass at least 20 out of 24 questions before they moved on to the next set. Problem set 1 focused on place values of decimals less than 1. Problem set 2 focused on place values of decimals greater than 1. Problem set 3 focused on representing decimals less than 1, and problem set 4 focused on representing decimals greater than 1.

In the second session, the students used Motion Math Zoom for about 30 minutes. The students worked on the first several levels to unlock higher levels. They then practiced levels 12-16, decimals in tenths and hundredths. The students practiced with the needle option off in the first half of the session, and then turned on the needle to increase the challenge level. The students then spent 20 minutes working on two problem sets in Splash Math, comparing decimals less than 1 and greater than 1. Each had 24 questions.

In the third session, the students worked on problem sets 10-12 in the decimals section in Splash Math. Problem set 10 included 21 questions, focused on ordering decimals less than 1,. Problem set 11 included 24 questions, focused on ordering decimals greater than 1 (basic). Problem set 12 included 20 questions focused on ordering decimals greater than 1 (advanced).

In the fourth session, the students used Long Multiplication for about one hour. At the beginning of the session, they were told to set the upper number to be two-digit, and the lower number to be one-digit. Once they showed mastery in solving the problems, they were allowed to work on more complicated problems, such as multiplication of five-digit numbers by two-digit numbers.

Assessments

Three paper and pencil assessments were administered to the students to measure their learning from the math apps. In each assessment, the students spent 15 minutes on a pre-test before they used the apps and 15 minutes on the same test (post-test) after they used the apps. The assessments were designed to be similar to the problems that the students practiced on the apps, but none of the same problems from the apps were used in the assessments. Each question in the assessments was assigned one point.

Assessment 1 included 20 multiple-choice questions on place values in decimals, for example, (1) What is the digit in the tenths place in the number of 2.65?, (2) What is the place of the underlined digit: 0.57?, (3) What decimal number is marked on the number line?, and (4) What decimal number does the following represent: 2+0.3+0.04? All students took the pre- and post-test of Assessment 1, but during the class time one student left the classroom without using the apps, so that student was excluded from analysis.

Assessment 2 included 19 multiple-choice questions on comparing and ordering decimals, for example, (1) Which number is the greatest in the following numbers?, (2) Compare the decimal numbers. Put <, =, or > between the two numbers, (3) Write any decimal number between 3.09 and 4.20, and (4) Arrange the three decimal numbers from greatest to the least: 0.45, 0.89, 0.9. Assessment 2 was administrated three times to the students. The pre-test was conducted before the students used the math apps. Assessment 2 had two post-tests because the students used different apps for comparing and ordering decimals in two class sessions. All students took the pre-test and the first post-test of Assessment 2. One student was absent and did not take the second post-test.

Assessment 3 included 15 questions that asked students to calculate the product of a two-

Table 1
Pre- and post-test results for three assessments
Note. The total points are 20 for Assessment 1, 19 for Assessment 2, and 15 for Assessment 3.

			N	Mean	STD
Assessment 1	Pre	All	17	12.4	4.12
		Typical	8	13.9	2.75
		Struggling	9	11.1	4.83
	Post	All	17	16.9	2.59
		Typical	8	17.8	1.83
		Struggling	9	16.2	3.03
Assessment 2	Pre	All	18	10.7	4.58
		Typical	8	12.8	3.24
		Struggling	10	9.0	4.94
	Post1	All	18	12.5	4.30
		Typical	8	15.0	2.88
		Struggling	10	10.5	4.30
	Post2	All	17	14.5	2.92
		Typical	7	15.4	2.94
		Struggling	10	13.9	2.88
Assessment 3	Pre	All	17	7.7	4.39
		Typical	8	10.0	2.27
		Struggling	9	5.6	4.85
	Post	All	17	9.9	4.07
		Typical	8	11.8	1.58
		Struggling	9	8.3	4.97

digit number and a one-digit number, such as 15 × 6, 75 × 7, and 85 × 9. During the class time, one student with special needs could not focus on class work due to an emotional disturbance, so he did not take Assessment 3.

In addition, Splash Math tracked student progress and provided a summary of student performance. Such progress data provided a detailed record on the number of math problems that students solved and their scores. The researchers also took field notes during the class sessions concerning students' engagement levels when they were using the apps.

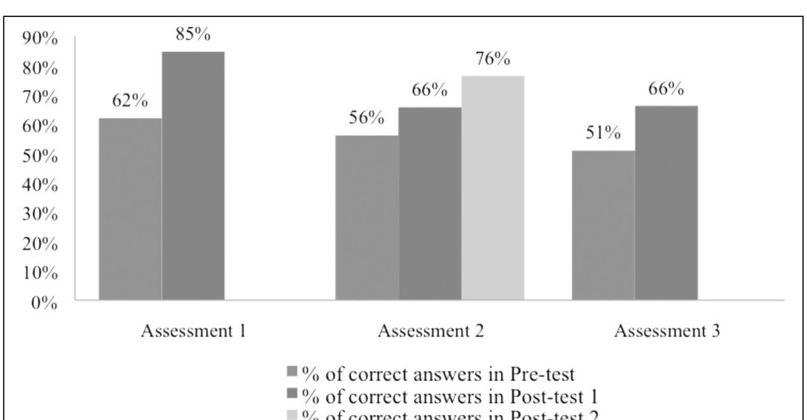

Figure 4: Percentage of correct answers in three assessments

Data analysis

For each pre- and post-test, the number of questions that the students answered correctly was tabulated. Mean scores and standard deviations were calculated. Because the assessments had different total points, to facilitate comparison, the students' improvement in scores was converted into percentages. Two-tailed paired sample *t*-tests were conducted to examine whether the differences between the pre- and post-tests for the three assessments were statistically significant.

In addition, the students were divided into two groups. Group 1, referred to as the struggling group, included four students with special needs and six students at-risk. Group 2, referred to as the typical group, included seven students without any label and one gifted student. We analyzed the differences between the two groups in both the pre- and post-test of the three assessments. Due to the small sample size, only the percentage of improvement was compared.

Results

As shown in Table 1, the students improved their performance in each of the three assessments after using the math apps. Paired-sample *t*-tests showed that the differences between the pre- and post-tests were all statistically significant. Figure 4 shows the improvement by percentage that the students made in the three assessments.

Place values in decimals

The t-test indicated a significant improvement from the pre-test to the post-test of Assessment 1 ($t(16) = 3.872$, $p < .01$), after using the Splash Math app for 40 minutes. The mean score went up from 12.4 out of 20 in the pre-test to 16.9 in the post-test. Analysis of students' work history in Splash Math showed that the students practiced the four sets of problems 1.58, 1.27, 2.00, 1.09 times, respectively, to meet the criteria that the teacher set, e.g., 20 out of 24 correct answers (see Table 2). The percentages of improvement in the four problems sets from their first attempt to the best scores were 9.79%, 0.38%, 14.77%, and 9.26%. Because each problem set had 24 questions, the students practiced an average of 143 math problems in the first session. Classroom observation showed that the students were generally engaged in the app.

Table 2

Summary of student work history on the Splash Math app

1. Due to the fact that we had to return the iPads borrowed from other teachers immediately after class, we were not able to save data from all the students for this app.

2. Some students did not complete the whole problem set in the class session because they spent more time ordering decimals less than 1, so the average number of attempts was less than 1.

Class	Math task	N[1]	Number of attempts	Average score in first attempt	Average best score	Improvement from first attempt to best score (%)
Session 1	Decimal place value: Decimals less than 1	12	1.58	19.82	22.17	2.35 (9.79%)
	Decimal place value: Decimals greater than 1	11	1.27	23.18	23.27	0.09 (0.38%)
	Represent decimals less than 1	11	2.00	18.64	22.18	3.55 (14.77%)
	Represent decimals greater than 1	11	1.09	19.78	22.00	2.22 (9.26%)
Session 2	Compare decimals greater than 1	12	1.08	21.82	22.45	0.64 (2.65%)
	Compare decimals less than 1	12	1.08	22.08	22.67	0.58 (2.43%)
Session 3	Order decimals less than 1	16	2.31	16.13	18.56	2.44 (11.61%)
	Order decimals greater than 1 (basic)[2]	17	0.94	21.64	21.79	0.14 (0.60%)
	Order decimals greater than 1 (advanced)[2]	17	0.65	16.71	17.67	0.95 (4.76%)

Comparing and ordering decimals

The t-tests indicated continuous improvement from the pre-test to the first post-test (t (17) = 3.108, p < .01), from the first post-test to the second post-test (t (16) = 3.05, p < .01), and from the pre-test to the second post-test (t (16) = 4.631, p < .001) in Assessment 2. The mean score went up from 10.7 out of 19 in the pre-test, 12.5 in the first post-test, and 14.5 in the second post-test.

Classroom observations suggested that the students were most engaged in the task when they used the Motion Math Zoom app, especially when they turned on the needle option. The teacher commented that he had never seen the class so engaged in a math task.

Two-digit by one-digit multiplication

The students made significant improvement from the pre-test to the post-test of Assessment 3 (t (16) = 2.889, p < .05), after using the Long Multiplication app for one hour. The mean score went up from 7.7 out of 15 in the pre-test to 9.9 in the post-test, representing 15% of improvement.

Classroom observations suggested that the students were engaged in using the app in general, but some students became bored with the app towards the end of the class session. Some students kept changing the background of the app, which was one of the few features they could change in the app.

Achievement gap between struggling learners and typical learners

In all of the three assessments, the average scores in both the pre and post-test of the typical group outperformed the struggling

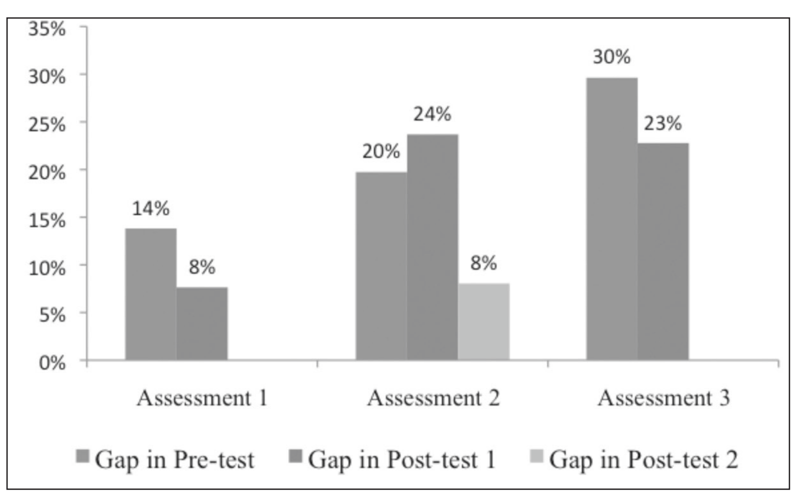

Figure 5: Gaps between struggling group and typical group in three assessments

group, as shown in Table 1. Both groups made improvement after the use of math apps. However, the struggling group made larger gains in three assessments, and the achievement gap between the two groups was reduced. As shown in Figure 5, the gap between the two groups was reduced from 14% to 8% in Assessment 1 and from 30% to 23% in Assessment 3. In Assessment 2, the gap between the two groups was slightly increased in the first post-test. However, in the second post-test, the gap was reduced from 24% to 8%, suggesting that the struggling group caught up with more practice.

Discussion

This study found encouraging evidence on using math apps to improve student learning and close the achievement gap between struggling students and typical students. Prior research has shown that struggling learners benefit from computer-enhanced math intervention (Burns, Kanive, & DeGrande, 2012), but little is known about the effectiveness of math apps. This study found that use of math apps may be an effective practice in providing instructional supports for struggling students within general education classrooms. First, struggling students have more room for improvement than typical students. Second, the affordances of math apps, such as self-pacing, immediate feedback, and breaking down complex processes into small steps, may be even more beneficial for struggling students. It is not uncommon that in regular math instruction, struggling students are unable to keep up with the pace of general students (Baker, et al., 2002). In summary, there is a potential for using well-designed math apps to help struggling students achieve the Common Core State Standards for Mathematics.

In addition, the student learning records provided by the Splash Math app were valuable because they allowed the teacher to track student progress, understand students' weak areas, and plan instruction accordingly. If the pre- and post-tests showed student learning as a result of using math apps, the learning records revealed the process of how the learning happened. Many students in this study made more than one attempt to practice the problem sets to achieve the correction rate set by the teacher, which was unlikely to occur in a paper and pencil condition because it is hard to provide students immediate feedback. Also, the finding that the students solved an average of 143 problems in one class session suggests that math apps may allow students to solve more problems than using paper and pencil, as reported in a study that compared iPads and worksheets on math skills of high school students with emotional disturbance (Haydon et al., 2012).

Although this study found that apps were generally engaging to students and easy to use, there is room for apps to improve their design. For example, Motion Math Zoom can be improved by allowing users to customize the settings, so students do not have to start from level 1 in order to unlock next levels, when they do not need to practice integral numbers from 1 to 1,000. The Long Multiplication app can be improved by making its interface more appealing and adding some gaming components (e.g., rewards, points) for students. Both apps should track student work history, like what Splash Math does, and provide individual and aggregated progress reports to teachers.

It should be noted that due to the small sample size and the short study duration, findings in this study may not be generalized to a larger population. Research on tablets in classrooms is still in its infancy. More studies should be conducted to identify effective math apps, particularly for struggling learners.

Notes

1. The number of apps in the major app stores is available at http://www.appannie.com/search/?vertical=apps&market=ios. App Annie is a mobile analytics company.

Acknowledgement

This material is based on work supported by the University Research Institute at the University of Texas at El Paso. Any opinions and findings expressed in this material are those of the author and do not necessarily reflect those of the University Research Institute.

Meilan Zhang *is an Assistant Professor of Educational Technology in the Department of Teacher Education at the University of Texas at El Paso. Her research interests focus on improving student learning using digital technologies, and helping preservice and inservice teachers integrate cutting-edge technologies into teaching. Please direct correspondence regarding this article to her at EDUC 801D, 500 W. University Ave., El Paso, TX, 79968; Email: mzhang2@utep.edu; Tel: 734-709-9756; Fax: 616-777-1305*

Robert P. Trussell *is an Associate Professor of Special Education in the Department of Educational Psychology and Special Services, College of Education, at the University of Texas at El Paso. He also directs Project CHANGE (Children with Autism Need a Great Education). His research interests focus on positive behavior supports in schools.*

Benjamin Gallegos *is a doctoral student at the University of Central Florida. He is interested in the role of digital technologies in improving student learning.*

Rasmiyeh R. Asam *is a graduate student in the Department of Teacher Education at the University of Texas at El Paso. She is pursuing a master's degree in science education.*

References

Apple Press. (2013, May 16). Apple's App Store marks historic 50 billionth download. Retrieved from http://www.apple.com/pr/library/2013/05/16Apples-App-Store-Marks-Historic-50-Billionth-Download.html

Baker, S., Gersten, R., & Lee, D.-S. (2002). A synthesis of empirical research on teaching mathematics to low-achieving students. *The Elementary School Journal, 103*(1), 51-73.

Barringer, M.-D., Pohlman, C., & Robinson, M. (2010). *Schools for all kinds of minds: Boosting student success by embracing learning variation*. San Francisco, CA: Jossey-Bass.

Brosvic, G. M., Dihoff, R. E., Epstein, M. L., & Cook, M. L. (2006). Feedback facilitates the acquisition and retention of numerical fact series by elementary school students with mathematics learning disabilities. *Psychological Record, 56*(1), 35.

Burns, M. K., Kanive, R., & DeGrande, M. (2012). Effect of a computer-delivered math fact intervention as a supplemental intervention for math in third and fourth grades. *Remedial and Special Education, 33*(3), 184-191.

Carpenter, T. P., Levi, L., Berman, P., & Pligge, M. (2005). Developing algebraic reasoning in the elementary school. In T. A. Romberg, T. P. Carpenter & F. Dremock (Eds.), *Understanding mathematics and science matters* (pp. 81-98). Mahwah, NJ: Erlbaum.

Chang, W.-L., Yuan, Y., Lee, C.-Y., Chen, M.-H., & Huang, W.-G. (2013). Using Magic Board as a teaching aid in third grader learning of area concepts. *Educational Technology & Society, 16*(2), 163-173.

Cheung, A., & Slavin, R. E. (2013). The effectiveness of educational technology applications on mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review, 9*, 88-113.

Geist, E. A. (2012). A qualitative examination of two year-olds interaction with tablet based interactive technology. *Journal of Instructional Psychology, 39*(1), 26-35.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*, 81-112.

Haydon, T., Hawkins, R., Denune, H., Kimener, L., McCoy, D., & Basham, J. (2012). A comparison of iPads and worksheets on math skills of high school students with emotional disturbance. *Behavioral Disorders, 37*(4), 232-243.

Hill, D. (2008, October 31). Android Market, Unleashed. Retrieved from http://www.medialets.com/android-market-unleashed/

iDevBooks. (2012). Long Multiplication (Version 2.3) [Mobile application software]. Retrieved from http://itunes.apple.com

Kirby, K. D. d. (2013, April). *The development of an idealized number line: Differentiating physical inscription from mathematical object*. Paper presented at the annual meeting of American Educational Research Association, San Francisco, CA.

Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. *Educational Psychology Review, 22*(3), 215-243.

Martinie, S. (2013, April). *Decimal fractions: An important point*. Paper presented at the annual meeting of American Educational Research Association, San Francisco, CA.

Motion Math. (2012). Motion Math: Zoom Pro (Version 1.0) [Mobile application software]. Retrieved from http://itunes.apple.com

National Center for Education Statistics. (2013). *National Assessment of Educational Progress (NAEP), various years, 1990-2013 Mathematics Assessments*. Washington, D.C.: U.S. Department of Education, Institute of Education Sciences.

National Council of Teachers of Mathematics. (2000). Principles and standards for mathematics education. Reston: National Council of Teachers of Mathematics.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). Common Core State Standards for Mathematics. Washington, D. C.: Authors.

Paek, S., Saravanos, A., & Black, J. B. (2012, April). *Studying the impact of input method on the modality principle*. Paper presented at the annual meeting of American Educational Research Association, Vancouver, British Columbia, Canada.

Peluso, D. C. C. (2012). The fast-paced iPad revolution: Can educators stay up to date and relevant about these ubiquitous devices? *British Journal of Educational Technology, 43*(4), E125-E127.

Pilli, O., & Aksu, M. (2013). The effects of computer-assisted instruction on the achievement, attitudes and retention of fourth grade mathematics students in North Cyprus. *Computers & Education, 62*(0), 62-71.

Rathouz, M. M. (2011). Making sense of decimal multiplication. *Mathematics Teaching in the Middle School, 16*(7), 430-437.

Saxe, G. B. (2012, April). *Learning mathematics through representations: Overview*. Paper presented at the annual meeting of American Educational Research Association, Vancouver, British Columbia, Canada.

Segal, A. (2011). *Do gestural interfaces promote thinking? Embodied interaction: Congruent gestures and direct touch promote performance in math.* Unpublished dissertation, Columbia University, New York.

Slavin, R. E., & Lake, C. (2008). Effective programs in elementary mathematics: A best evidence synthesis. *Review of Educational Research, 78*(3), 427-515.

Steckroth, J. J. (2010). From calculating to calculus. *Teaching Children Mathematics, 16*(5), 292-299.

StudyPad. (2012). 4th Grade Math: Splash Math Worksheets Game for Kids (Version 2.4.0) [Mobile application software]. Retrieved from http://itunes.apple.com

Vaughn, S., Wanzek, J., Murray, C. S., & Roberts, G. (2012). Intensive interventions for students struggling in reading and mathematics: A practice guide. Portsmouth, NH: RMC Research Corporation, Center on Instruction.

Yeh, S. S. (2010). The cost effectiveness of 22 approaches for raising student achievement. *Journal of Education Finance, 36*(1), 38-75.

Zisimopoulos, D. A. (2010). Enhancing multiplication performance in students with moderate intellectual disabilities using Pegword mnemonics paired with a picture fading technique. *Journal of Behavioral Education, 19*(2), 117-133.