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ABCmouse Mastering Math™ Significantly Accelerates Early Mathematics Learning

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Key Findings

- With 5 hours of total usage over a 10-week period, ABCmouse Mastering Math accelerated pre-k and kindergarten math learning gains by 36%.
- The more students used Mastering Math, the greater their learning gains.
- The greatest impacts were found on the most difficult math skills.
- Teachers recognized the value of Mastering Math for personalizing learning and advocated for continued use.

Overview

With only 40% of students proficient in math by 4th grade,[1] the U.S. faces an acute need to scale innovative approaches to help close the math achievement gap. Closing this gap is particularly critical in order to support effective Science, Technology, Engineering, and Mathematics (STEM) learning and prepare the future workforce for twenty-first-century careers. Yet there remain few evidence-based and engaging digital learning resources to accelerate early math learning. To address this need, a cluster randomized controlled study was conducted to evaluate the impact of Age of Learning's ABCmouse Mastering Math, a digital math program for young learners. For this study Age of Learning partnered with WestEd, a nonprofit research, development, and service agency with deep expertise in evaluating the impact of educational programs. Age of Learning researchers collected the data for the study and collaborated with researchers in WestEd's STEM Program to analyze and interpret the data.[††††]

ABCmouse Mastering Math is one component of the overarching ABCmouse® *Early Learning Academy* program. Mastering Math is an adaptive game-based curriculum designed to help children build a strong understanding of fundamental number sense concepts and operations, from recognizing numbers and basic counting up through adding and subtracting three-digit numbers. With engaging characters and scenarios, individualized learning pathways, and continuous assessment built into every level of every game, Mastering Math is designed to accelerate children's achievement of mastery. Starting with a research-based knowledge map of learning objectives and their prerequisite relationships and based on each student's performance, the adaptive system decides what games to recommend at which difficulty level and uses variable scaffolding personalized for each learner.

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1 NCES. (2018). *2017 NAEP Mathematics and Reading Assessments: Highlighted Results at Grades 4 and 8 for the Nation, States, and Districts.* Retrieved from https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2018037.

Figure 1. Sample pretest

Figure 2. Sample activity

At the time of this study, Mastering Math contained 29 games addressing granular skills within number recognition, forward and backward counting, and counting from 1 to 20. Each game includes up to six learning activities at various difficulty levels, including a pretest and an in-game mastery check called the "boss" level. Figure 1 is a screenshot of the pretest for a game addressing the learning objective "count out, with numbers 1 to 5," and Figure 2 is a screenshot of the boss level of the game, in which children are asked to drag the target number of "Shapeys™" (the characters in the game) onto the boat.

Students can *acquire* mastery by failing a pretest and passing the corresponding boss level. Students can *demonstrate* mastery by passing the pretest, passing the boss level, or getting placed out of a skill by passing a more advanced skill. Students can complete the game if they demonstrate mastery of all skills in the app, at which point they receive practice boss levels on high-level skills. Mastering Math is available as an app for smartphones and tablets and in both English and Spanish, but all treatment students in this study used the English-language version.

Participants

A total of 453 students (51% female, 76% Hispanic, 22% African American) participated in the study. They came from 20 kindergarten (K) and transitional-kindergarten (TK[2]) classrooms at four Title I elementary schools in urban Southern California. Prior to the start of the study, TK and K classrooms within each school were randomly assigned into the treatment or control groups. The treatment group consisted of ten K classes, and the control group of eight K and two TK classes. Each school housed four to six participating classrooms. One of the control classrooms was designated as a bilingual classroom.

At the start of the study, students' mean age was 5.44 (*SD* = .36, ranged 4.81 to 6.65). Age distributions were similar between the two groups. The treatment group (*M* = 5.50, *SD* = .32) was slightly older than the control group (*M* = 5.37, *SD* = .39) but the difference was not statistically significant, accounting for clustering effects (students were nested within classrooms, $p = .11$). Assessments were administered in the child's preferred language, with 5.3% of students at pretest and 3.5% at posttest tested in Spanish or both English and Spanish.

Students who did not take both the pretest and posttest were excluded from the analytic sample for the outcome measure.[3] The final analytic sample contained 428 students with complete pre- and posttest data. There were no statistically significant group differences in attrition, age, gender, or pretest language.

[2] Transitional kindergarten (TK) is the first year of a two-year program in the California K-12 public school system for four-year-olds who will turn five after the start of the school year.

[3] The following analyses excluded (1) 24 students who moved away or to another school and did not receive the posttest, (2) 7 students who were enrolled in participating schools during the implementation period and did not receive the pretest, and (3) one student who was transferred from a control classroom to a treatment classroom. There were two students who moved from one treatment classroom to another, each within the same school, and they were kept in the analyses under the original teacher assignment. There was no cluster-level attrition.

Design and Procedure

This study had a multi-site cluster random assignment design. Treatment classrooms received full access to the Mastering Math app in fall 2017 and were asked to implement the app in small groups for 15 minutes per day, 3 days per week, for 9 to 11 weeks during the study period. Control classrooms did not receive Mastering Math access and conducted business-as-usual instruction. For the implementation period, each treatment classroom received six tablets with access restricted to Mastering Math. Control classrooms did not have tablet access.

Prior to implementation, treatment teachers received a one-hour training on how to operate the tablets and Mastering Math. Treatment teachers received weekly email reminders of usage and summary of student usage during the week. Usage data was gathered from the Mastering Math app.

The primary measure of children's mathematics knowledge was the *Test of Early Mathematics Ability, Third Edition* (TEMA-3), a standardized and nationally norm-referenced measure of mathematics performance of children from age 3 to 8 years 11 months.[4]

In this study, a modified assessment was created using a subset of 19 out of 72 items from TEMA-3 Form A that best represented the numeracy skills covered by Mastering Math. The selected items were not over-aligned with the intervention; none of the TEMA-3 items were identical to the activities in Mastering Math, and some TEMA-3 items required students to extend their knowledge beyond Mastering Math (e.g., concretely modeling word problems and mental addition).

Trained child assessors administered the assessment one-on-one to students as pre- and posttests. The pretest was administered in September prior to the implementation period; the posttest in November and early December following the implementation period. Assessors were blind to students' condition assignment at both assessment timepoints.

Following the posttest, all teachers completed a survey on their math curriculum coverage during the study period and on the impact of Mastering Math (or educational technology, for the control group) on students' early math learning. Eight of ten control teachers reported having used educational technology (via the computer lab) for math instruction during the implementation period. Of the eight, six reported using My Math[5] (three of them in conjunction with another program, i.e., My Math, Starfall,[6] and something else), and two reported using ST Math.[7]

Treatment students spent 5.22 hours on average (*SD* = 2.97 hours)—between 28 and 35 minutes per week—on Mastering Math, completing 79 learning activities on average (*SD* = 40.93). They acquired mastery of 2.21 skills (*SD* = 5.10) and received instruction (the teaching level following a failed pretest) on an average of 11.5 skills (*SD* = 6.12). Forty-five students (20%) completed the entire game, demonstrating mastery on all 29 skills (by pretest or by passing the mastery level).

Results

Using rigorous methods, results reveal that Mastering Math significantly accelerated learning gains after an average of 5.2 hours of usage total over the course of 10 weeks. To control for students' performance at pretest, we used a three-level hierarchical linear model (HLM) to account for differences by students based on their pretest score, group assignment, and school.[8] This enabled us to compare the treatment group's posttest outcomes against the control group after adjusting for differences in baseline scores.

4 Ginsburg, H. & Baroody, A. (2003). *TEMA-3 Examiners Manual (3rd ed.)*. Austin, TX: PRO-ED.

5 McGraw-Hill Education (Firm). (2014). *My Math*. Columbus, OH: McGraw-Hill Education.

6 Starfall Education Foundation (Firm). 2017. *Starfall*. Boulder, CO: Starfall Education Foundation.

7 MIND Research Institute (Firm). (2017). *Spatial-Temporal Math (ST Math)*. Irvine, CA: MIND Research Institute.

8 The HLM model included students' pretest scores on mathematics knowledge and skills (PRE) as a covariate in the Level 1 model. The Level 2 model included the intervention variable (TREAT), and the Level 3 model contained the school-level effects. The models were specified as the following:
Level 1: $yijk = \pi 0jk + \pi ijk PRE ijk + eijk$
Level 2: $\pi 0jk = \beta 00k + \beta 01k TREAT jk + r0jk$
Level 3: $\beta 00\kappa = \gamma 000 + \mu 00k$
$\beta 01k = \gamma 010 + \mu 01k$
μ00k are fixed effects associated with each school mean, constrained to have a mean of 0, and μ01k are fixed effects associated with each treatment-by-school interaction, constrained to have a mean of 0.

Finding 1. ABCmouse Mastering Math significantly accelerated math learning gains

Mastering Math produced significantly higher gains in children's mathematics knowledge and skills than business-as-usual instruction. The treatment group outperformed the control group by 5.71 percentage points at posttest, and this difference was statistically significant after controlling for differences in pretest (p = .03; effect size = 0.23,[9] see Table 1). Figure 3 displays the pretest and posttest percent correct by experimental condition.[10] Overall, the treatment group had 36% greater gains in math knowledge than the control group.

Table 1. Impact Analysis of Student Outcome Measures

	Adjusted Mean *(SD)*		Adjusted Mean Difference[b]	*P-Value*	*Effect Size*
	Treatment[a]	Control[a]			
Pretest % Correct	43.56 (25.21)	40.07 (24.80)	3.49	0.33	0.14[c]
Posttest % Correct	62.15 (24.61)	56.44 (25.06)	5.71	0.03	0.23[d]

[a] *Treatment n = 233, control n = 195.*

[b] *Pretest difference is in adjustable range.*

[c] *Effect size was calculated by dividing the adjusted mean difference by the full sample unadjusted standard deviation of the pretest.*

[d] *Effect size was calculated by dividing impact estimate by the full sample unadjusted standard deviation of the outcome variable.*

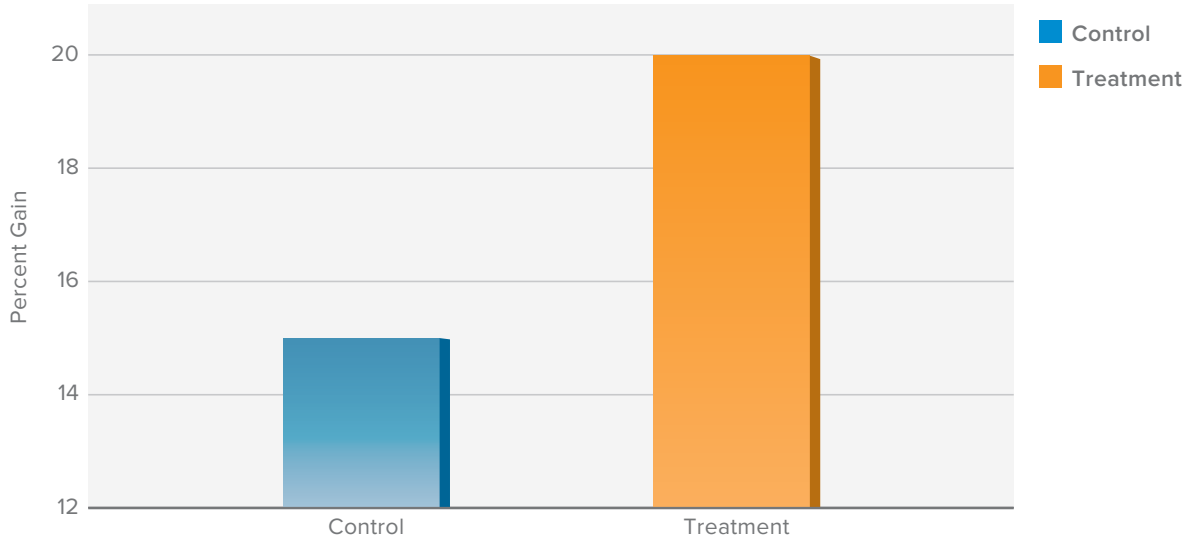

Figure 3. Percent gain in TEMA-3 math scores by treatment group students who used Mastering Math (n = 233) and control group students who did not (n = 195, p < .05 , effect size = 0.23).

[9] Effect size was calculated by dividing the impact estimate by the full sample unadjusted standard deviation of the outcome variable.

[10] The baseline difference between treatment and control groups (effect size = 0.14) is between 0.05 and 0.25 standard deviations, which is in statistical adjustment range to meet federal What Works Clearinghouse baseline equivalence requirements.

Figure 4 shows learning gains by pretest score. Mastering Math produced the greatest learning gains in students who scored in the middle third at pretest (n = 150, point of estimate = 7.28, p = .04, effect size = 0.46). Students who scored in the top third at pretest also showed statistically significantly greater gains than similarly scoring peers from the control group (n = 149, point of estimate = 5.87, p = .01, effect size = 0.37).

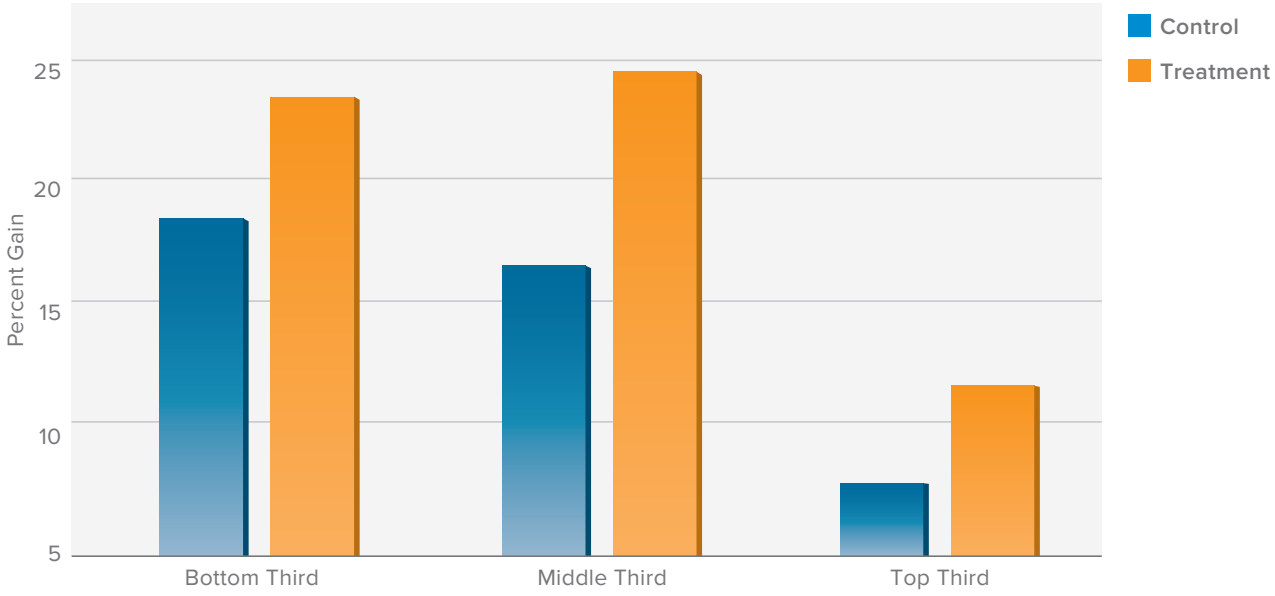

Figure 4. Percent gain in TEMA-3 math scores based on prior knowledge for treatment and control group students based on the approximate top, middle, and bottom thirds at pretest (p < .04, effect size = 0.46). Cutoffs were as follows: top third TEMA-3 score > 50% correct (control n = 67, treatment n = 82); middle third ≤ 50% correct and > 23% correct (control n = 70, treatment n = 80); bottom third ≤ 23% correct (control n = 58, treatment n = 71).

Finding 2. The more students used ABCmouse Mastering Math, the greater their learning gains

Treatment group students on average started 11.5 games (SD = 6.12) and completed 2.21 games (SD = 5.10) by passing the boss level. The more games students started, the greater their learning gains, r = .19, p < .01. For children who successfully completed at least one boss level, there was a significant correlation between the number of games mastered and learning gains, r = .38, p < .01.

Finding 3. The greatest impacts from ABCmouse Mastering Math were found on the most difficult skills

Among the skills addressed by the TEMA-3, Mastering Math produced the greatest gains on the most difficult skills (see Figure 5). Research suggests that kindergarten teachers spend most of their time on the basic math skills of simple counting and shape recognition, even though the majority of children enter kindergarten having already mastered these skills and would benefit from being exposed to more advanced content.[14]

On numbers greater than 10, while there were no significant differences between treatment and control groups at pretest, at posttest, 36% of treatment versus 26% of control were able to name the number after (10-20, X^2 [3, N = 428] = 10.65, p = .05), and 53% of treatment versus 42% of control were able to read teen numerals (X^2 [3, N = 428] = 11.96, p = .03).

[11] Engel, M., Claessens, A., & Finch, M. A. (2013). Teaching students what they already know? The (mis)alignment between mathematics instructional content and student knowledge in kindergarten. *Educational Evaluation and Policy Analysis, 35*(2) 157-178.

On verbally counting backward, while there were no significant differences between treatment and control groups at pretest, at posttest 57% of treatment versus 42% of control were able to count backward from 10 correctly (X^2 [3, N = 428] = 13.64, p = .05), and 21% of treatment versus 8% of control were able to count backward from 20 correctly (X^2 [3, N = 428] = 15.64, p = .02).

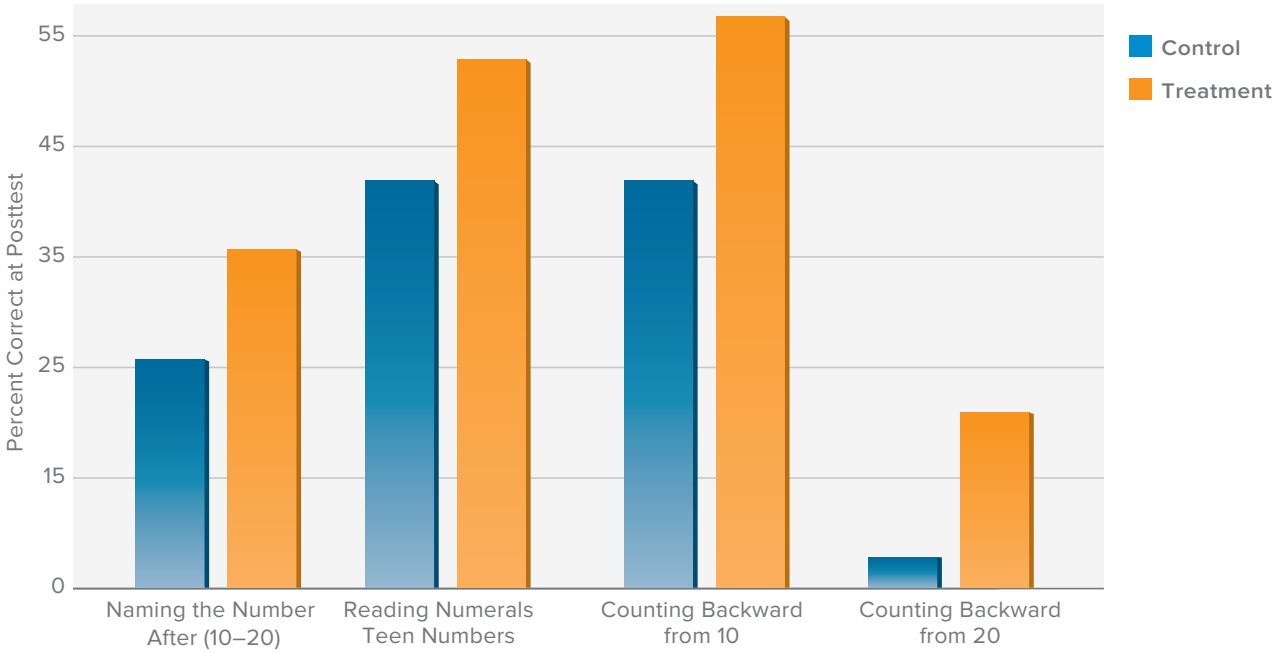

Figure 5. Percent correct on the most difficult TEMA-3 items at posttest for treatment and control groups (*n's* for students that correctly answered each item varied between 48–132 for treatment and 16–81 for control, *p's* ≤ .05).

Finding 4. Teachers recognized the value of ABCmouse Mastering Math for personalizing learning and advocated for continued use

Among the treatment group teachers,

- **100%** reported a positive or highly positive experience using Mastering Math in their classroom. 100% reported meaningful (medium or high) impact on counting skills and identifying numbers.
- **100%** of teachers reported meaningful impact on their students' interest in learning math and self-confidence in learning math.
- **100%** of teachers agreed or strongly agreed that their students have enjoyed using Mastering Math, that they find it to be a valuable math learning resource, that it adapts to their students' needs, and that they want to continue using Mastering Math in their teaching.

Conclusion

This was the first study to evaluate the impact of Age of Learning's ABCmouse Mastering Math app on students' math learning in kindergarten classrooms. Using rigorous methods, students who used Mastering Math were found to have significantly greater growth in their math knowledge than their control group peers. Notably, these accelerated gains were found with relatively little time spent on the intervention: an average of 5.2 hours of usage in total or about 30 minutes per week over the course of 10 weeks.

The impacts of Mastering Math are greatest for those students who have some prior, basic number sense (i.e., in the zone of proximal development) and/or who were more engaged in using the app. Importantly, Mastering Math had the greatest impacts on the most difficult, and most likely to be overlooked by teachers, math skills for young learners. Lastly, teachers recognized the value of Mastering Math as a resource to personalize learning and one that they want to continue using.