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Improving Outcomes for At-Risk Prekindergarten and Kindergarten Students with a Digital Learning Resource

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Introduction

School failure often begins in the early grades. Research establishes that low academic skills in reading, math, and general knowledge in kindergarten are the strongest predictors of grade retention[1] and later academic success.[2-5] Kindergarten students who are below grade level in reading and mathematics skills (who also tend to be of low socioeconomic status or SES) are more likely to remain behind their peers throughout their education.[6-9] As hundreds of thousands of children enter kindergarten each year without the necessary academic skills for success in school,[10-12] it is imperative that we examine the efficacy of educational programs and the resources intended to supplement those programs for learning, particularly in reading and mathematics.

We know that high-quality early childhood education programs are positively associated with academic outcomes at the end of preschool and kindergarten, especially for children who are at risk of school failure.[13,14] We also know that certain instructional strategies and environmental characteristics tend to be effective for developing early reading and mathematics skills, such as a literacy-rich classroom environment, instruction that builds upon children's natural curiosity in mathematics, extensive professional development for teachers, and opportunities for social collaboration among students.[15-17] There is not a clear consensus, however, on the impact of educational technology on young children's learning and development of early academic skills.[18-20]

Increasingly, researchers are recommending that educational technology and interactive media—when used actively, intentionally, and appropriately as a supplemental resource—can support and extend traditional educational materials in valuable ways.[21-24] There is indeed some early evidence that when those criteria are met, supplemental technology-based instruction in early learning programs can support and strengthen young children's learning and development in social, cognitive, language, literacy, writing, and mathematics domains.[25-31] However, What Works Clearinghouse finds very few studies examining the effectiveness of educational technology that met their standards of scientific rigor, and the few that did had mixed results.[32] Several meta-analyses have been conducted on the impact of educational technology and found promising results, but the effects tend to be small and fluctuate by subject domains.[33-37] When there are positive results, educational technologies tend to benefit low-SES students most because they have fewer educational resources in their homes and communities.[38,39] More research is needed to better understand the short- and long-term impacts of educational technology in early education, especially in preparing at-risk children for school.

In two related studies, this longitudinal research examines the effectiveness of ABCmouse® *Early Learning Academy*, a popular online comprehensive curriculum for children ages 2 to 8, as a supplemental learning resource for remediating the risk of school failure and supporting academic growth in kindergarten. In Study 1, prekindergarten teachers integrated ABCmouse into their instruction without specific requirements for frequency or amount of usage. The study examined differences in assessment scores at the beginning and end of the school year based on the natural variation in usage of ABCmouse, in particular how ABCmouse could independently contribute to improvements in scores that indicate kindergarten readiness.

The results of Study 1 inspired new questions about the continued impact of ABCmouse in kindergarten, leading to a quasi-experimental design for Study 2 in which all 33 district kindergarten classrooms were asked to integrate ABCmouse into instruction for 45 minutes per week per student over the course of the school year. The students in 2 elementary schools had limited access to ABCmouse literacy activities for the first semester and full ABCmouse access for the second semester. These classrooms served as a comparison group for the classrooms in 2 elementary schools with full access to ABCmouse curriculum for the entire school year. Study 2 explored how the Study 1 sample progressed in kindergarten compared to their peers who were not enrolled in the district prekindergarten program with ABCmouse and examined the impact of variation in ABCmouse access and usage during the kindergarten year on pre-post score changes.

Study 1

Methods

Design. Study 1 had a naturalistic design in which prekindergarten students had varying usage of ABCmouse during the school year. ABCmouse *Early Learning Academy* is a comprehensive supplementary online curriculum. At the time of the study, ABCmouse included more than 5,000 learning activities available through a website and a mobile app, with a subset of learning activities available via YouTube videos and a DVD of music videos. This curriculum was developed by education and technology experts and includes games, books, puzzles, videos, and so forth in the academic domains of literacy, language, math, science, social studies, art, and music for children ages 2 to 6. Currently, ABCmouse includes additional content that was not available at the time of this research. Children are able to independently explore the curriculum on ABCmouse in 3 ways: 1) free exploration, in which the child selects any activities of interest; 2) guided learning, in which the teacher assigns specific activities and lessons based on the child's needs; and 3) through a planned curriculum called the *Step-by-Step Learning Path,* which provides predesignated learning activities at the child's assigned level (toddler, preschool, prekindergarten, or kindergarten).

Participants. The sample consisted of 230 students (49% male, 51% female) enrolled in 12 classrooms within the public school district prekindergarten (DPK) program in Tupelo, Mississippi. Children with missing assessment data were excluded from the analyses, resulting in 204 students with complete data. Analyses showed no statistically significant differences in usage or demographics between students with and without missing data. Enrollment in the prekindergarten program was determined according to each child's level of risk for school failure: children with low pretest scores, English language learners, children with developmental disabilities/delays, and/or children living in poverty or homelessness. The sample was demographically diverse with 43% Caucasian, 43.5% African American, 10.4% Hispanic, and 3% Asian children; 51.3% of the total sample qualified for the free/reduced lunch program. While a large majority of students were identified as disadvantaged in some way, not all DPK students met district criteria for risk. At the start of the prekindergarten school year, the mean age of DPK students was 4.43 (SD = .30, range = 3.70 - 4.96).

Measures. Each child was assessed with the Early Prevention of School Failure Assessment (EPSF). The EPSF was developed in the late 1980s and is a validated instrument commonly used in Mississippi.[40] Its 48 items are appropriate for prekindergarten in the assessment of language and cognition. The language subscales are 1) vocabulary, 2) listening and following directions, 3) rhyming, 4) using a story, 5) printing, and 6) spoken language. The cognition subscales are 1) identification of color, 2) shape identification, 3) use of numbers, 4) size and seriation, 5) visual memory, and 6) classification. Cronbach's alphas of these subscales prior to prekindergarten ranged .59 - .73 for language and .57 - .87 for cognition. The intercorrelations among these subscales were positive and statistically significant (Pearson's r range = .29 - .87, p's < .001). The EPSF yields a score from 0 to 100; the school district uses a score of 41 to 59 as indication that the child is at target (i.e., not at risk for school failure).

Age of Learning, Inc., the developer of ABCmouse, provided back-end data on student use. These data included the number of learning activities completed and the time each student spent on ABCmouse. No data were collected on how teachers integrated the curriculum into their instructional strategies or daily routines.

Procedures. The EPSF assessment was administered by school district personnel in May/June 2013 to screen students for eligibility for the prekindergarten program and again in April 2014 to assess student risk for failure in kindergarten. This assessment was scheduled and administered for district purposes, and the data were then shared with the researchers.

From August 2013 to May 2014, DPK teachers were encouraged to use the digital curriculum as a supplemental resource to supplement and enhance their teaching for all students. The teachers integrated ABCmouse into whole-group, small-group (teacher-directed), and individualized (student-directed) learning. With ABCmouse, teachers can differentiate instruction by remediating specific skills for students who have not mastered them and enriching the curriculum for all students. Teachers were able to assign activities to each student according to the topic or skill they were teaching for the week and/or to place students on the *Step-by-Step Learning Path* based on EPSF pretest scores and other factors.

Teachers also encouraged parents to access students' ABCmouse account at home, enabling students to complete activities at home that had been assigned by the teacher. While researchers provided teachers with recommendations on best practices for using ABCmouse in the classroom, the teachers were not directed on when or how to integrate the online curriculum within their classroom routines or the length of time that students should spend on ABCmouse.

Preliminary analyses.

Pre-EPSF performance. Table 1 shows the distribution of students' EPSF performance in the summer preceding prekindergarten (pre-EPSF) and at the end of prekindergarten (post-EPSF). Almost half of the students (45.7%) scored less than 40% correct on the pre-EPSF.

Table 1. Breakdown of EPSF Score Ranges at the Start and End of Prekindergarten: Below Target (< 40% Correct), At Target (41-59% Correct), Above Target (≥ 60% Correct)

	Pre-EPSF (May/June 2013)		Post-EPSF (April 2014)	
EPSF Performance	N	Percent of Total	N	Percent of Total
Below target	105	45.7	53	23.0
At target	45	19.6	41	17.8
Above target	59	25.7	130	56.5
Unknown (missing EPSF)	21	9.1	6	2.6

ABCmouse usage. Variation in ABCmouse usage was expected due to the naturalistic design. Participating DPK students spent an average of 308 minutes on ABCmouse in total (about 5.13 hours, ranging from 0 to 101.77 hours) and completed a mean of 65 learning activities (median = 35, range = 0 - 551, including repeats) during the prekindergarten school year (2013-2014). Of those 230 DPK students, 37 spent no time on the site and 44 completed 0 activities. Those students were included in the analyses; only students with missing assessment data were excluded.

Results

The more ABCmouse learning activities a student completed, the greater his or her kindergarten readiness score at the end of prekindergarten, indicating a reduction in the level of risk for school failure.

The variation in ABCmouse usage during the prekindergarten year allowed for a comparison of usage as both a continuous and categorical variable. The more ABCmouse learning activities completed, the greater the student's EPSF score at the end of DPK. A multiple linear regression model confirmed that the number of ABCmouse learning activities completed was a significant predictor of EPSF growth, controlling for the effect of age and pretest EPSF score, $F(3,188) = 35.70$, $p < .001$, $R^2 = .36$. For each additional 10 activities completed, an additional .5 points gain can be expected from pretest to posttest, over and above the effect of pretest and age, $\beta = .20$, $p = .001$. Pretest score was also a reliable predictor of EPSF growth: The lower the students scored on the pretest, the stronger the growth, $\beta = -.55$, $p < .001$, controlling for the number of activities completed. Age was not a reliable predictor. There was no reliable correlation between pretest score and total activities completed.

Figure 1 shows the pre- and post-EPSF scores by the number of learning activities completed. While there was no significant difference in their pre-EPSF scores at the outset, students who completed at least 35 activities (median activities completed by the sample) individually during prekindergarten experienced significantly higher growth—an additional 65% gain—on the EPSF compared to those who completed fewer than 35 activities, $t(202) = 3.39$, $p = .001$, $d = .47$.

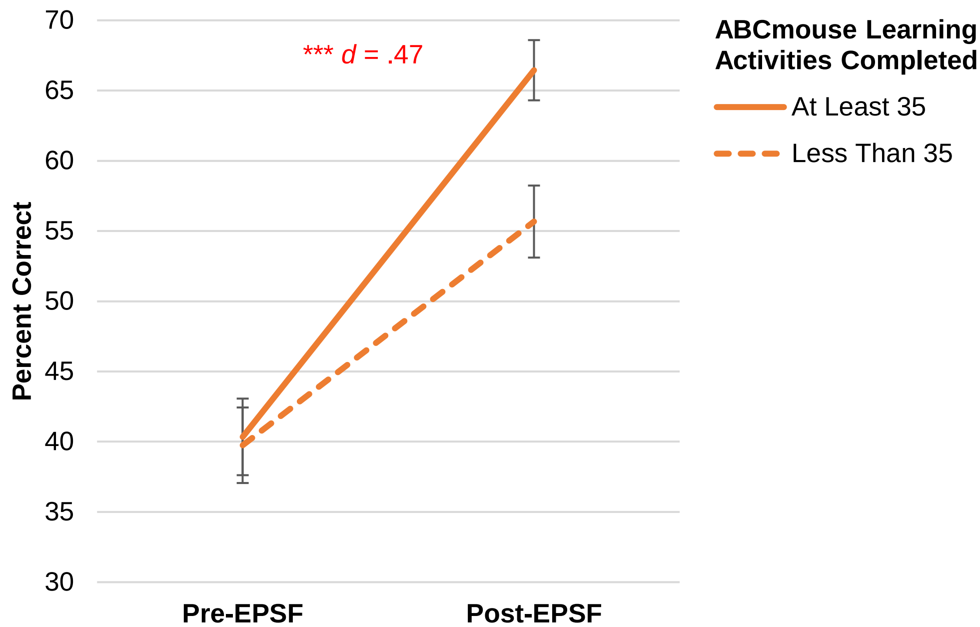

Figure 1. Mean Pre-EPSF and Post-EPSF Scores by the Number of ABCmouse Learning Activities Completed

Note: Error bars represent ± 1 standard error. *** = $p < .001$.

This effect was notably strong for "below-target" scorers on the pretest, $t(101) = 4.50$, $p < .001$, $d = .89$. It was marginally significant for "at-target" scorers, $t(41) = 1.87$, $p = .07$, $d = .48$, and not statistically significant for those who scored "above-target." This is expected as the "above-target" group started in prekindergarten with high scores and had a limited range of growth on the EPSF. Figure 2 shows these results.

Students who shifted from "below-target" at pretest to "at-target" or "above-target" at posttest completed significantly more ABCmouse activities than peers who remained "below-target" at the end of the year (averaged 77 vs. 27 activities, respectively, $t[101] = 3.24$, $p = .002$, $d = .72$), as seen in Figure 3.

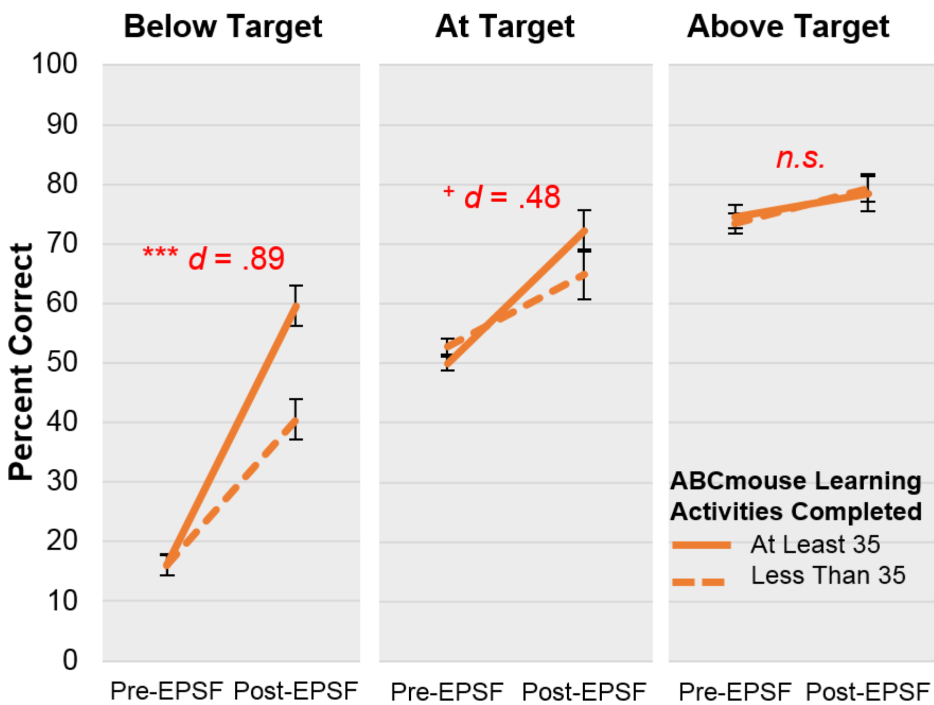

Figure 2. Mean Pre-EPSF and Post-EPSF Scores by the Number of ABCmouse Learning Activities Completed and by Pre-EPSF Score Group

Note: Error bars represent ± 1 standard error. *** = $p < .001$, + = $p < .10$, *n.s.* = p > .10.

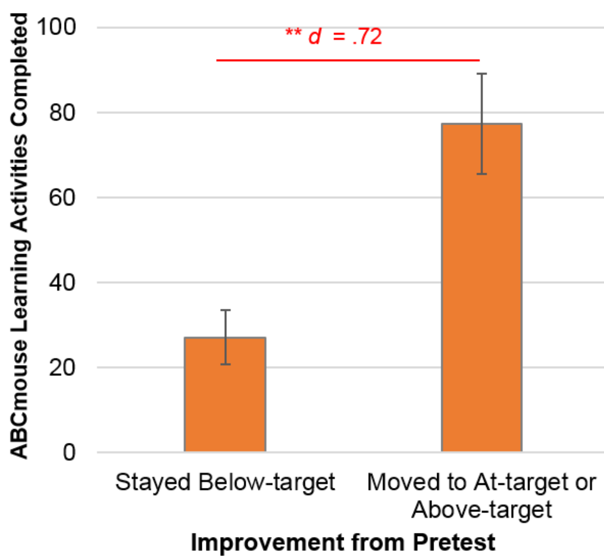

Figure 3. Mean Number of ABCmouse Learning Activities Completed by Whether or Not Students Improved on the EPSF at the End of Prekindergarten

Note: Error bars represent ± 1 standard error. ** = $p < .01$.

Study 2

Methods

Design. Study 2 had a quasi-experimental design, in which a district administrator chose at random from Tupelo Unified School District's 4 elementary schools, 2 schools to be in the treatment group and the other 2 to be in the comparison group. All kindergarten classrooms in the schools assigned to the treatment group had full access to ABCmouse for the entire school year (Full-access Group), while all kindergarten classrooms in the two schools assigned to the comparison group had limited access to literacy and full access to math activities on ABCmouse for the first half of the year and full access to the entire ABCmouse curriculum for the second half (Restricted-access Group). There were no known differences among the schools at the time of group assignment (see Preliminary Analyses section, below).

Participants. Most of the DPK students from Study 1 participated in Study 2. The Kindergarten (K) sample consisted of 571 students: 210 were students from the DPK sample, and 361 students had not been enrolled in the district prekindergarten program (non-DPK); no information on their early education experience prior to kindergarten was provided. A total of 33 classrooms participated in the study, with each school housing 8 to 9 kindergarten classrooms of 12 to 20 students in each classroom. DPK students were distributed across the 4 schools depending on typical residential requirements. All but one classroom enrolled DPK students from Study 1. Demographics for the K sample in Study 2 were similar to those of the DPK sample in Study 1 with the exception of age. The mean age for the K sample at the start of the kindergarten year was 5.65 (SD = .41, N = 564). Non-DPK kindergarten students were slightly older than DPK kindergarten students who were from the Study 1 sample (M = 5.72 and 5.52, respectively), $t(543) = 6.05$, $p < .001$, $d = .52$. There were no statistically significant age differences between the Restricted- and Full-access Groups (M = 5.63 and 5.63, respectively), nor between schools (M range = 5.60 - 5.67). Table 2 displays the 4 experimental groups and sample sizes per group.

Table 2. Sample Sizes by Experimental Groups

		ABCmouse Access Group		
		Restricted access	**Full access**	**Total**
DPK Status	**Non-DPK**	169	192	361
	DPK	119	91	210
		228	283	571

Note: There were 230 original DPK students in Study 1; 20 did not enroll in a district elementary school so were not included in Study 2. Actual sample sizes varied by analyses (i.e., not all students took all assessments at all 3 time points).

Measures. All 33 kindergarten classrooms implemented a similar assessment schedule and used identical instruments, administered by the classroom teacher—STAR™ Early Literacy and Early Numeracy,[41] Classworks® Reading and Math,[42] and DIBELS® (Dynamic Indicator of Basic Early Literacy Skills).[43] STAR and Classworks were administered at 3 time points, and DIBELS was assessed only at the end of the school year. The intercorrelations among the STAR, Classworks, and DIBELS measures at all time points were positive and statistically significant (Pearson's r range = .29 - .65, p's < .001).

The STAR assessment consists of 10 subscales (7 involving word knowledge and other language-related skills, 2 related to comprehension strategies and construction of meaning, and 1 involving numbers and operations). A scaled score (SS) is calculated based on the difficulty of the questions and the number of correct responses from the subscales. It ranges from 300 to 900, which reflects the age range for which STAR Early Literacy was designed, from about 3 to 9 years. A child's stage of literacy development can be inferred from the SS with the following 4 Literacy Classifications: Early Emergent Reader (300-487), Late Emergent Reader (488-674), Transitional Reader (675-774), and Probable Reader (775-900). For analytic purposes in evaluating changes in Literacy performance, the scores from the 9 STAR Literacy subscales (all but Early Numeracy) were summed to form the STAR Literacy Composite.

The Classworks assessment consists of 15 reading/language arts items, such as word analysis and reading comprehension, as well as 15 math items, such as numeration and measurement. Lastly, the DIBELS consisted of 4 skills: LNF (Letter Naming Fluency), PSF (Phoneme Segmentation Fluency), NWFCLS (Nonsense Word Fluency Correct Letter Sounds), and NWFWWR (Nonsense Word Fluency Whole Word Reading). Each of the subscales was standardized and averaged to form the DIBELS Literacy Composite.

Procedures. In September 2014, 2 elementary schools were assigned to receive full access to ABCmouse for the entire school year, and 2 schools received restricted access during the first semester and full access during the second semester. This study design was used to address the school district's concerns about equity and avoided entirely depriving the comparison group of an educational resource. The Restricted-access Group had full access to math activities and limited access to literacy activities prior to the switch in late January, while the Full-access Group was able to use all elements of the ABCmouse curriculum for this grade level, which consists primarily of literacy activities and some math and other activities. Unlike Study 1 where there was no requirement for the frequency or amount of ABCmouse to be integrated into instruction, in this study teachers were asked to comply with a 45-minute per-week, per-student minimum usage requirement.

Students were tested on the STAR and Classworks assessments at 3 time points: 1) September 2014, prior to assignment of ABCmouse access (T1); 2) December 2014, prior to the switch of the comparison group from Restricted-access to Full-access (T2); and 3) June 2015 (T3). DIBELS was assessed once at T3.

Preliminary Analyses.

Pretest. At the start of kindergarten, 85% of students were classified as "emergent" readers. There were more "early emergent" readers in the non-DPK group than in the DPK group, $\chi^2(3) = 27.4$, $p < .001$, but different schools and access groups in kindergarten had similar literacy distributions. Table 3 displays the distribution by groups and by schools.

There were no reliable differences between students in the Full-access and Restricted-access Groups on the STAR Literacy, STAR Early Numeracy, and Classworks Math. The Restricted-access Group started with slightly higher scores on the Classworks Reading than the Full-access Group (M = 1214.62 vs. 1210.23, t[537] = 2.62, p = .009, d = .23). We controlled for variations in starting scores whenever possible in the analyses.

Table 3. Classification of Reading Skills of Kindergarten Students at the Beginning of the School Year

Groups	Early Emergent	Late Emergent	Probable	Transitional	Unknown	Total by Group
Non-DPK	36.8%	49.3%	1.1%	6.6%	6.1%	361
DPK	24.3%	60.5%	2.4%	10.5%	2.4%	210
Full-access	33.9%	53.7%	0.0%	8.1%	4.2%	283
Restricted-access	30.6%	53.1%	3.1%	8.0%	5.2%	288
By School						
Elem 1	31.0%	57.7%	0.0%	5.6%	5.6%	142
Elem 2	30.9%	53.0%	2.7%	6.0%	7.4%	149
Elem 3	36.6%	50.0%	0.0%	10.6%	2.8%	142
Elem 4	30.4%	52.9%	3.6%	10.1%	2.9%	138
Total by Skill Level	184	305	9	46	27	

ABCmouse Usage. Teachers attended a short training prior to the start of the school year. The high variation in both time spent and the number of activities completed on ABCmouse (described below) within and between classrooms points to a diversity of implementation practices.

Out of the 571 K students, 24 had missing usage data because they could not be identified in the ABCmouse database (13 were from the DPK sample). There were no statistically significant differences in assessments scores between students with and without usage data. The remaining 547 K students spent an average of nearly 28 hours using ABCmouse in total (range = 0 - 141 hours) and completed an average of 390 learning activities (range = 0 - 5266, including repeats) during the kindergarten school year (2014-2015); 15 students completed 0 activities on the site.

Figure 4 shows the breakdown of activities completed by subjects from each group. It was expected that the Restricted-access Group would have less ABCmouse usage overall, from September 2014 to January 2015, because the majority of the typical ABCmouse curriculum at the kindergarten grade level consists of reading activities. The Full-access Group averaged more than 3 times as many reading activities as the Restricted-access Group (223.2 vs 68.8) and 37% more activities overall (332.1 vs 242.4) from September 2014 to January 2015, prior to the switch, $t(569) = 3.76$, $p < .001$, $d = .31$. Sixty-two percent of the learning activities completed by the Restricted-access Group were math activities, and 30%

were reading activities.[a] For the Full-access Group, this pattern was reversed: 66% of the learning activities completed were reading activities and 26% were math activities. As a result of the research design, the Full-access Group had not only greater access to the full ABCmouse curriculum but also completed many more activities, especially reading activities, than the Restricted-access Group. Therefore, “regular usage” refers to both the access type and higher usage levels of the Full-access Group, and “limited usage” refers to both the limited access and lower usage levels of the Restricted-access Group.

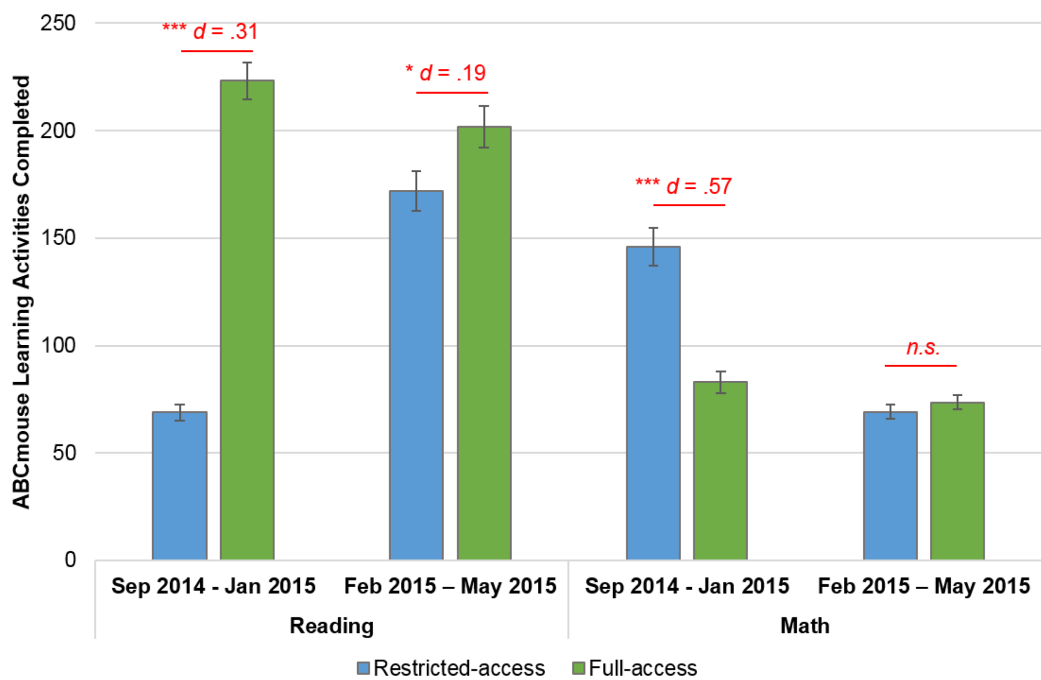

Figure 4. Average Number of Primarily Reading and Math ABCmouse Learning Activities Completed by Group

Note: Error bars represent ± 1 standard error. *** = $p < .001$, * = $p < .05$, *n.s.* = p > .10.

After the switch, in the period between February 2015 and May 2015, the two groups completed a similar number of learning activities (Full-access: $M = 302.42$, $SD = 228.47$; Restricted-access: $M = 304.09$, $SD = 374.61$). There was no statistically significant difference in the number of learning activities completed in kindergarten between those who attended

[a] A learning activity can have multiple subject areas associated with it (e.g., a book on counting can be considered a reading activity as well as a math activity). Here we report the primary subject assigned to each activity.

the district prekindergarten program and those students who did not (DPK: M = 466.62, SD = 456.26: Non-DPK: M = 446.37, SD = 333.90). The Restricted-access and Full-access Groups experienced a similar curriculum during this time period, in which 62% and 66% of the activities completed were reading (for Restricted-access and Full-access, respectively) and 26% of the activities completed were math (for both groups).

Results

1. Regular ABCmouse usage in kindergarten helped to accelerate students' learning gains in literacy and mathematics skills.

By assessment performance T1-T2. As seen in Figure 5, students in the Full-access Group (who had regular ABCmouse usage) performed significantly better—with 120% greater gain—than those in the Restricted-access Group (who had limited usage) on Classworks Reading from T1 to T2. A 2 (DPK, non-DPK) x 2 (Restricted-access, Full-access) analysis of covariance (ANCOVA) on T1-T2 Classworks Reading growth with T1 Classworks Reading scores as a covariate confirmed the effect of ABCmouse access type on Classworks Reading. As previously stated, during the first semester the Full-access Group had substantially greater access to ABCmouse literacy activities and completed many more learning activities overall than the Restricted-access Group. Thus, when comparing the effect of these two conditions, we report on the cumulative effect of access and usage. Students in the Full-access Group made significantly greater gains between T1 and T2 than those in the Restricted-access Group, $F(1, 528) = 59.89$, $p < .001$, $\eta_p^2 = .10$, after controlling for the effect of the students' starting scores. An independent t-test confirmed this effect, $t(531) = 7.66$, $p < .001$, $d = .66$. The impact of students' starting score on the Classworks Reading had a significant effect on the gain score, $F(1,528) = 8.15$, $p = .004$, $\eta_p^2 = .02$. The lower the score at T1, the greater the growth at T2, $r(534) = -.30$, $p < .001$. There was no significant difference between DPK students and non-DPK students and no significant interaction of DPK x access type.

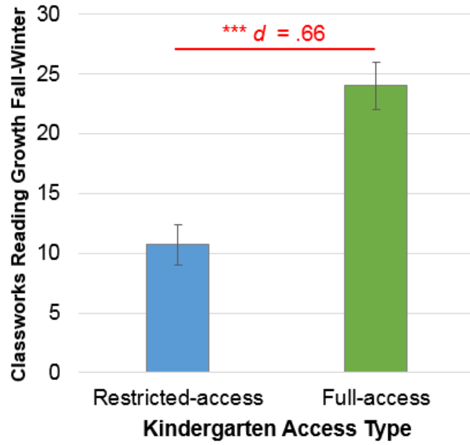

Figure 5. Mean Classworks Reading Growth from T1-T2 by Access Group in Kindergarten

Note: Error bars represent ± 1 standard error. *** = $p < .001$.

There was no reliable difference between the Full-access and Restricted-access Groups on STAR Literacy growth from T1 to T2, but students who had regular ABCmouse access and usage for the whole school year were more likely to meaningfully improve their STAR Literacy scores than those who had limited usage. As seen in Table 4, a higher proportion of students in the Full-access Group advanced their STAR Literacy classifications from T1 to T3 than students in the Restricted-access Group, 88.1% vs 79.3%, respectively, $\chi^2(2) = 7.84$, $p = .02$.

Table 4. Number of Students Whose Literacy Classification Did Not Change, Moved Up, or Moved Down by Access Type

Group	Did not change	Moved up	Moved down	Total
Restricted-access	52	214	4	270
Full-access	30	238	2	270

Similarly, students in the Full-access Group also made significantly greater gains—an additional 150%—than those in the Restricted-access Group (M = 28.58 vs. 10.69, respectively) on early mathematics skills, $F(1, 529) = 21.09$, $p < .001$, $\eta_p^2 = .04$, after controlling for the effect of the students' starting scores. An independent t-test confirmed this effect, $t(533) = 3.49$, $p = .001$, $d = .30$. DPK enrollment also had a reliable impact on Classworks Math growth: Students from the DPK program in Study 1 tended to have higher gains than non-DPK peers, $F(1,529) = 7.48$, $p = .006$, $\eta_p^2 = .01$. There was no significant interaction of DPK x access type.

There was no reliable difference between the Full-access and Restricted-access Groups on STAR Early Numeracy growth from T1 to T2. However, a particularly strong effect of access type was found for non-DPK students at the end of the year.

By assessment performance T1-T3. In some cases, regular usage of ABCmouse helped non-DPK students catch up with their peers from the DPK program who entered kindergarten at a higher readiness level on both literacy and math. This was expressed in terms of gain scores on the Classworks and end-of-year raw performance on the STAR.

Overall, all groups started at similar levels in the fall of kindergarten on both Classworks Reading measures, but the DPK group ended kindergarten with higher scores than the non-DPK group at T3, $t(562) = 3.95$, $p < .001$, $d = .34$; see Figure 6a. Interestingly, however, the impact of DPK depended on the type of ABCmouse access students received in kindergarten.

A 2 x 2 ANCOVA on Classworks T1-T3 Reading growth confirmed a main effect of access type: by T3, students in the Full-access Group experienced significantly higher growth than those in the Restricted-access Group, after controlling for initial T1 scores, $F(1,528) = 4.01$, $p = .046$, $\eta_p^2 = .008$. The DPK students also exhibited overall higher growth than the non-DPK students, $F(1,528) = 10.98$, $p = .001$, $\eta_p^2 = .02$. There was also a significant interaction of DPK x access type, $F(1,528) = 4.81$, $p = .03$, $\eta_p^2 = .009$. While there was no difference between access type for DPK students, non-DPK students who had regular ABCmouse usage demonstrated significantly higher growth than non-DPK students who had limited usage, $t(325.74) = 3.85$, $p < .001$, $d = .42$. Within the Restricted-access Group, DPK students experienced higher literacy growth than non-DPK students, $t(248.08) = 4.04$, $p < .001$, $d = .50$, but there was no difference in growth between DPK and non-DPK within the Full-access Group. Figure 6b displays these results.

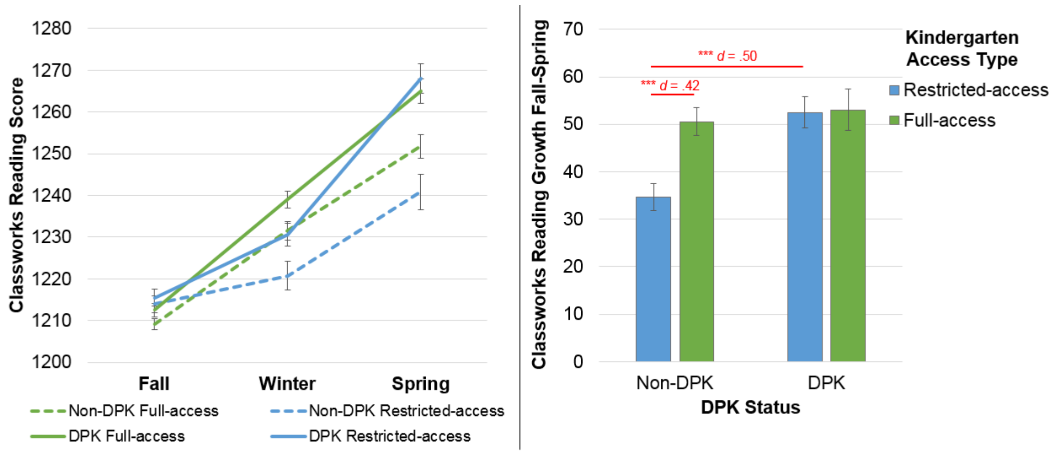

Figure 6. (a) Classworks Reading Scores at Each Time Point, (b) Classworks Reading Score Gain from T1-T3 by DPK Enrollment and ABCmouse Access Type

Note: Error bars represent ± 1 standard error. *** = $p < .001$.

Figure 7 shows the STAR Literacy scores across the kindergarten school year. DPK students started out with higher scores on the STAR Literacy than non-DPK students and did consistently better than non-DPK students throughout the year. However, when non-DPK students had regular ABCmouse usage for the full year, by T3 they were able to catch up with DPK students. These findings were confirmed by a 3 (T1, T2, T3) x 2 (DPK, non-DPK) x 2 (Full-access, Restricted-access) mixed ANOVA. There was a significant main effect of tests, $F(1,1072) = 1051.25$, $p < .001$, $\eta_p^2 = .66$, confirming that overall there was strong growth on the STAR Literacy throughout the year. There was a significant main effect of DPK status, $F(1, 536) = 15.56$, $p < .001$, $\eta_p^2 = .03$, and a significant DPK x access type interaction, $F(1, 536) = 4.43$, $p = .04$, $\eta_p^2 = .008$. Follow-up *t*-tests confirmed that while there are reliable differences between DPK and non-DPK students in the Restricted-access Group at all 3 time points ($t[271] = 3.69$, $p < .001$, $d = .45$ at T1, $t(271) = 4.44$, $p < .001$, $d = .55$ at T2, and $t(279) = 3.63$, $p < .001$, $d = .45$ at T3), the only reliable difference between the DPK and non-DPK students in the Full-access Group was at T1, $t(269) = 2.14$, $p = .03$, $d = .28$. There were no other statistically significant effects.

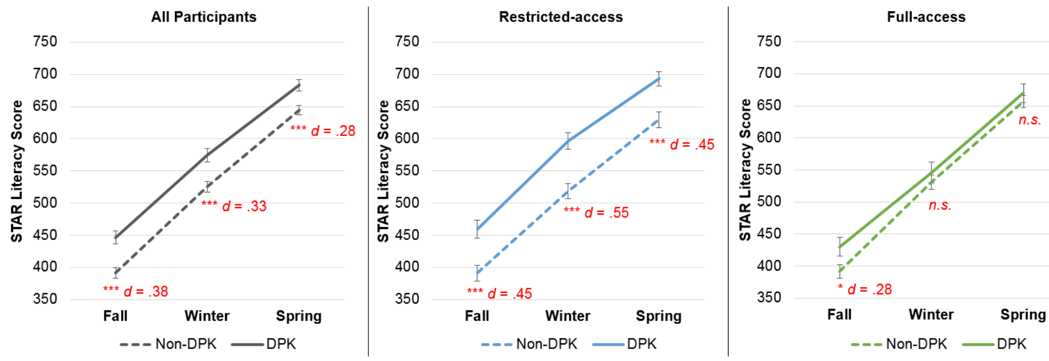

Figure 7. (a) STAR Literacy Scores of All Students Across the Kindergarten School Year, (b) Only for the Restricted-access Group, (c) Only for the Full-access Group

Note: Error bars represent ± 1 standard error. *** = $p < .001$, * = $p < .05$, *n.s.* = $p > .10$.

Similar to the literacy results, all groups started at similar levels in the fall of kindergarten on Classworks Math, but the DPK group ended kindergarten with higher scores than the non-DPK group at T3, $t(564) = 4.67$, $p < .001$, $d = .40$; see Figure 8a.

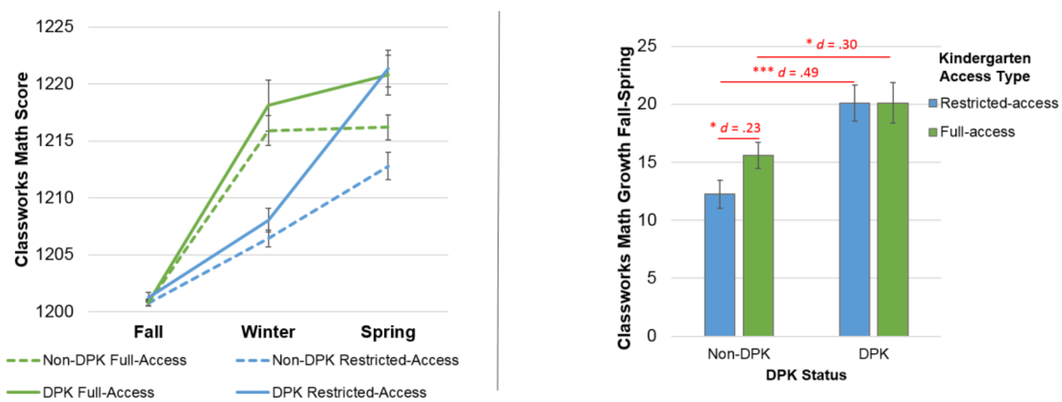

Figure 8. (a) Classworks Math Scores Across Groups by Time Point, (b) Classworks Math Score Gain Across Groups

Note: Error bars represent ± 1 standard error. *** = $p < .001$, * = $p < .05$.

Figure 8b displays performance on Classworks Math at each time point and growth by condition. As seen with Classworks Reading, non-DPK students who had regular ABCmouse access and usage (the Full-access Group) also showed significantly higher growth on math than non-DPK students who had limited access and usage (the Restricted-access Group;

t[323.48] = 2.04, *p* = .04, *d* = .23). Similarly, the DPK students experienced higher growth than non-DPK students regardless of access type, *F*(1,528) = 18.89, $p < .001$, $\eta_p^2 = .04$.

Figure 9 shows the Early Numeracy (EN) scores across the school year. Like the STAR Literacy, a 3 x 2 x 2 mixed ANOVA confirmed strong growth throughout the year on the STAR EN, *F*(2, 1072) = 1213.69, $p < .001$, $\eta_p^2 = .69$. The DPK group performed reliably better than the non-DPK group at all 3 time points, as confirmed by a statistically significant main effect of DPK status, *F*(1,536) = 15.08, $p < .001$, $\eta_p^2 = .03$. There was also a significant DPK x access type interaction, *F*(1,536) = 4.86, *p* = .03, $\eta_p^2 = .009$. Within the Restricted-access Group, the DPK students performed reliably better than the non-DPK students at all three time points (*p*'s < .001, d = .48 to .55). However, within the Full-access Group, the non-DPK students were able to catch up with the non-DPK students at the end of the year. The only reliable difference was found at T1, *t*(269) = 2.11, *p* = .04, *d* = .28. There was also a test x DPK interaction, *F*(2,1072) = 4.56, *p* = .01, $\eta_p^2 = .008$, suggesting that the advantage of DPK over non-DPK students was smaller at T3 than T1. There were no other reliable effects.

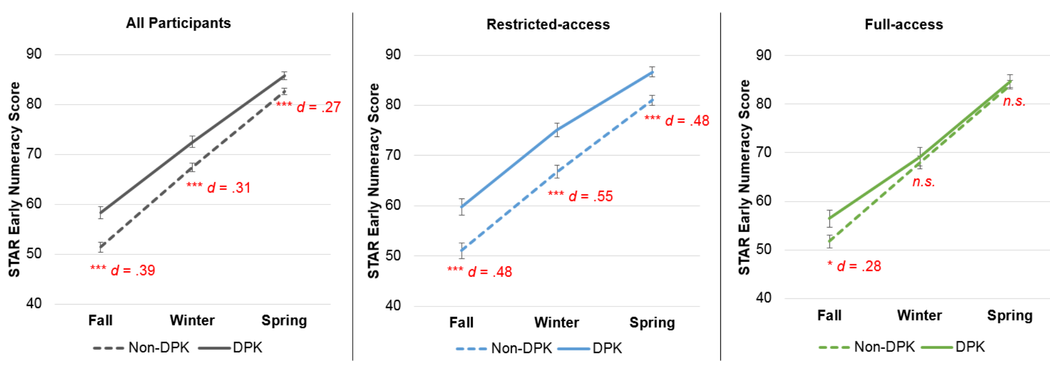

Figure 9. (a) STAR Early Numeracy Scores of All Students Across the Kindergarten School Year, (b) Only for the Restricted-access Group, (c) Only for the Full-access Group

Note: Error bars represent ± 1 standard error. *** = $p < .001$, * = $p < .05$, *n.s.* = $p > .10$.

By amount of usage. The more ABCmouse learning activities completed prior to T2 assessment, the stronger the T1-T2 learning growth on both Classworks Reading and STAR literacy. This was true regardless of whether students had full or restricted access to ABCmouse. Table 5 shows the results from multiple linear regressions predicting the growth on the STAR Literacy Composite and Classworks Reading scores from students' age, corresponding T1 scores, DPK enrollment, and total number of activities completed prior to the T2 assessment. The more ABCmouse learning activities completed, the stronger the learning growth on both the STAR Literacy composite and the Classworks Reading scores, controlling for age, performance at T1, and DPK enrollment. The expected increase in scores as a result of learning activities completed are higher when those learning activities came from the full ABCmouse curriculum than when they came from the restricted curriculum. With each additional 100 learning activities completed per student between T1 and T2, we can expect a 3-point increase from the Full-access Group and a 2-point increase from the Restricted-access Group on Classworks Reading, over and above the effects of T1 score and DPK status. These are sizable gains, given that the ranges of T1-T2 gain scores on Classworks Reading were -70 to 120 from the Full-access Group and -70 to 100 from the Restricted-access Group.

Table 5. Results from Multiple Linear Regression Analyses (Using Enter Method) Predicting STAR Literacy Composite and Classworks Reading T1-T2 Gain From Students' Ages, T1 Scores, DPK Statuses, and Number of Activities Completed Prior to the T2 Assessment

Condition	**Gain Score**	***F***	***p***	***R*²**	**Predictor**	***B***	***Beta***
Restricted-access (N = 262)	Classworks Reading T1-T2	12.88	< .001	.17	Activities Completed*	.02	.12
					Fall score***	-.48	-.36
					DPK**	10.33	.19
					Age*	10.13	.15
	STAR Literacy T1-T2	18.45	< .001	.22	Activities Completed**	.10	.15
					Fall score***	-.36	-.49
					DPK*	33.67	.15
					Age	13.31	.05
Full-access (N = 261)	Classworks Reading T1-T2	6.42	< .001	.10	Activities Completed*	.03	.02
					T1 score***	-.50	-.28
					DPK+	7.63	.11
					Age	3.52	.05
	STAR Literacy T1-T2	9.31	< .001	.13	Activities Completed***	.16	.19
					T1 score***	-.24	-.30
					DPK	-14.55	-.06
					Age	-14.10	-.05

Note: DPK was coded as 1 and non-DPK as 0; statistically significant predictors are marked as follows: *** = $p < .001$, ** = $p < .01$, * = $p < .05$, + = $p < .10$.

Similarly, with each additional 100 activities completed, we can expect a 16-point increase from the Full-access Group and a 10-point increase from the Restricted-access Group on the STAR Literacy, over and above the effect of T1 and DPK status. These are relatively large gains: the range of T1-T2 gain scores on STAR Literacy were -249 to 448 from the Full-access Group and -319 to 451 from the Restricted-access Group.

The total number of activities completed in the Full-access Group was also a reliable predictor of students' learning gains on the STAR Early Numeracy and Classworks Math from T1-T2, over and above the effect of students' ages, T1 scores, and DPK enrollment. For the Restricted-access Group, this effect was reliable only on the STAR Early Numeracy and not on the Classworks. Table 6 shows these results. With each additional 100 activities completed per student, we can expect a 2-point increase from the Full-access Group (T1-T2 difference scores range = -34 - 58 within this group) and a 1-point increase from the Restricted-access Group (range = 33 - 60) on the STAR EN, controlling for the effects of T1 score and DPK status. The Full-access Group can also expect an additional 2-point increase on the Classworks Math (T1-T2 difference scores range = -10 - 70 within this group), over and above the effects of T1 score and DPK status with each 100 additional activities completed. Scores at T1 were also a strong predictor of T1-T2 growth. The higher the STAR EN score at T1, the smaller the growth at T2, but the higher the Classworks Math score at T1, the stronger the Classworks growth.

Table 6. Results from Multiple Linear Regression Analyses (Enter Method) Predicting STAR EN and Classworks Math Gain From Students' Ages, T1 Scores, DPK Statuses, and Number of Activities Completed Prior to the T2 Assessment

Condition	Gain Score	*F*	*p*	R^2	Predictor	*B*	*Beta*
Full-access (N = 260)	STAR Early Numeracy Gain T1-T2	18.35	< .001	.18	Activities Completed**	.02	.18
					T1 score***	-.28	-.36
					DPK	-2.42	-.08
					Age	-1.95	-.06
	Classworks Math T1-T2	3.65	.02	.04	Activities Completed+	.02	.11
					T1 score*	1.01	.15
					DPK	2.92	.07
					Age	2.66	.06
Restricted-access (N = 261)	STAR Early Numeracy Gain T1-T2	42.06	< .001	.33	Activities Completed**	.01	.13

				T1 score***	-.43	-.61
				DPK*	3.52	2.34
				Age	1.81	.06
Classworks Math T1-T2	1.80	.15	.02	Activities Completed	.001	.02
				T1 score	.23	.09
				DPK	1.60	.09
				Age+	2.68	.12

Note: DPK was coded as 1 and non-DPK as 0; statistically significant predictors are marked as follows: *** = $p < .001$, ** = $p < .01$, * = $p < .05$, + = $p < .10$.

2. Longitudinally, the number of ABCmouse learning activities completed over both school years was a strong predictor of literacy and math outcomes.

We also examined the predictability of performance at the end of kindergarten based on ABCmouse usage over both prekindergarten and kindergarten school years. ABCmouse usage over both school years could reliably predict students' literacy and math performance at the end of kindergarten, after controlling for the effect of age, DPK participation, and ABCmouse access type received in kindergarten. Table 7 shows the results of a series of multiple linear regressions that confirm these findings.

Table 7. Multiple Linear Regression Predicting Each of the T3 Scores from Total Number of Learning Activities Completed in Prekindergarten and Kindergarten, Age, DPK Participation, and Access Type

Assessment	*F*	*p*	R^2	Predictor	*B*	*Beta*
Literacy at T3						
DIBELS	10.22	< .001	.08	Activities Completed***	.0003	.19
				Age*	.21	.11
				DPK participation	-.02	-.22
				Access type***	-.35	-.23
STAR Literacy	8.05	< .001	.06	Activities Completed***	.09	.21
				Age	6.85	.02
				DPK participation**	33.65	.12
				Access type	-9.56	-.03
Classworks Reading	14.12	< .001	.10	Activities Completed***	.030	.25
				Age*	8.29	.09
				DPK participation***	13.46	.17
				Access type	-.008	.00
Mathematics at T3						

STAR EN	7.79	< .001	.06	Activities Completed***	.008	.20
				Age	.89	.03
				DPK participation**	2.88	.12
				Access type	-.37	-.02
Classworks Math	16.74	<.001	.11	Activities Completed***	.01	.24
				Age**	4.53	.12
				DPK participation***	6.88	.20
				Access type	.03	.001

Note: DPK was coded as 1 and non-DPK as 0; Restricted-access as 0, Full-access as 1. Statistically significant predictors are marked as follows: *** = $p < .001$, ** = $p < .01$, * = $p < .05$, + = $p < .10$.

For each 100 additional ABCmouse learning activities completed, we can expect an increase of .03 points on the DIBELS composite, 9 points on the STAR Literacy, and 3 points on the Classworks Reading at T3, over and above the effects of students' age, DPK status, and ABCmouse access type. These are noteworthy increases, considering the range of total activities completed in both years was 0 to 5784 activities (including repeats) and the ranges of T3 scores were -2.02 to 2.96 on DIBELS composite (z-scores), 127 to 1655 on STAR Literacy, and 1200 to 1330 on Classworks Reading.

Similarly, we can expect with each 100 additional learning activities completed, a .8-point increase on the STAR EN and a 1.2-point increase on the Classworks Math. The range of STAR EN at T3 was 20 - 99, and the range of Classwork Math scores at T3 was 1200 - 1270. When both school years were taken together, access type during kindergarten was not a reliable predictor of students' performance at the end of kindergarten. However, DPK participation remained a strong, positive predictor for growth on the STAR and Classworks (but not on the DIBELS).

Discussion and Conclusion

We conducted two related studies to examine the impact of a supplemental online curriculum, ABCmouse, on early literacy and mathematics skills, with a particular focus on students identified as at risk for school failure. In the first study, ABCmouse was authentically integrated into classroom instruction in a district prekindergarten program designed to remediate the risk of school failure. We examined the relationship between ABCmouse usage and students' academic gains over that prekindergarten year. The second study followed those students' progress, as well as the progress of their peers, during kindergarten and compared the impact of varied levels of ABCmouse access and usage on early literacy and math gains. The results in both studies show that ABCmouse helps accelerate the acquisition of key literacy and math skills, with particularly strong effects for students whose initial assessment scores were below their peers.

DPK students from Study 1 scored higher on the initial assessments at kindergarten entry than non-DPK students. Yet ABCmouse usage was highly predictive of students' kindergarten readiness scores at the end of kindergarten. Students who completed more than 35 activities individually over the prekindergarten school year had much higher growth on the EPSF school readiness assessment than students who did not. This suggests that participation in DPK *in combination* with ABCmouse as a supplemental resource significantly reduced their risk of school failure.

In kindergarten, regular usage of ABCmouse also helped accelerate growth in both literacy and math skills. This was seen with T1-T2 and T1-T3 gains across both of the assessments (Classworks and STAR) that were given at 3 time points. Kindergarten students showed strong gains over the whole school year, but end-of-kindergarten performance was stronger with more robust ABCmouse usage. With regular ABCmouse usage, non-DPK students were able to catch up with their DPK peers at the end of kindergarten (T3). This finding was consistent across all 3 standardized assessments (Classworks, STAR, and DIBELS) that were given at the end of the kindergarten year.

Overall, the effect sizes of both literacy and math gains were notable, with particularly large effect sizes for literacy (from T1 to T2, d = .66 for literacy and .30 for math). This was similar to the catch-up effect of ABCmouse on non-DPK students in the Full-access Group (e.g., d = .42 for literacy and d = .23 for math).

Study 2 was limited by the lack of information about the prekindergarten experiences of the non-DPK students. Their performance on both assessments at the beginning of the kindergarten year indicated that they were, on average, not as well prepared as the DPK students who had 1 year of prior exposure to ABCmouse within the district prekindergarten program. But the analyses found that ABCmouse usage in the kindergarten year contributed independently and significantly to their ability to catch up with better-prepared peers. This suggests that ABCmouse could assist students from widely varying levels of competencies in achieving kindergarten goals by the end of that school year.

These studies build on prior research showing that the active and intentional use of developmentally appropriate educational technology can successfully support and enhance learning.[21-24] Prior to each study, teachers received training on the effective use of ABCmouse with age-appropriate levels of the curriculum to supplement and enhance their instruction. During the studies, they were encouraged and regularly reminded via email to maintain the recommended usage amount of 45 minutes per week per student. We found that learning gains were directly linked to the amount of ABCmouse usage students experienced.

These findings also offer converging evidence of the impact of ABCmouse on learning through different research designs (naturalistic and quasi-experimental), school contexts (prekindergarten and kindergarten), assessments (EPSF, Classworks, STAR, and DIBELS), and learning domains (literacy, mathematics) over a 2-year period. In this research, comparisons between different amounts of ABCmouse usage yielded strong findings; it is possible that ABCmouse would be found to have an even greater impact if regular usage of ABCmouse were compared to a no-usage (or business-as-usual) condition.

The findings from these studies highlight the value of ABCmouse as a supplemental educational resource in both prekindergarten and kindergarten. This research contributes to the growing evidence that the appropriate and intentional integration of well-designed educational technology into the classroom can positively impact student learning. As education continues to evolve, particularly in the early years of school, educational technology has the potential to meet the needs of students, teachers, and families to help children, especially children at risk for school failure, to learn and achieve grade-level objectives.

References

1. Davoudzadeh P, McTernan ML, Grimm KJ. Early school readiness predictors of grade retention from kindergarten through eighth grade: A multilevel discrete-time survival analysis approach. *Early Child Res Q*. 2015;32:183-192. doi:10.1016/j.ecresq.2015.04.005
2. Duncan GJ, Dowsett CJ, Claessens A, et al. School readiness and later achievement. *Dev Psychol*. 2007;43(6):1428-1446. doi:10.1037/0012-1649.43.6.1428
3. Krajewski K, Schneider W. Early development of quantity to number-word linkage as a precursor of mathematical school achievement and mathematical difficulties: Findings from a four-year longitudinal study. *Learning Instruction*. 2009;19(6):513-526. doi:10.1016/j.learninstruc.2008.10.002
4. Claessens A, Engel M. How important is where you start? Early mathematics knowledge and later school success. *Teachers Coll Rec*. 2013;115(6):1-29. http://www.tcrecord.org/Content.asp?ContentId=16980. Accessed September 1, 2016.
5. Manfra L, Dinehart LHB, Sembiante SF. Associations between counting ability in preschool and mathematic performance in first grade among a sample of ethnically diverse, low-income children. *J Res Child Educ*. 2014; 28(1):101-114. doi:10.1080/02568543.2013.850129
6. Sarama J, Clements DH. *Early Childhood Mathematics Education Research: Learning Trajectories for Young Children*. New York, NY: Routledge; 2009. doi:10.4324/9780203883785
7. Denton K, West J. Children's reading and mathematics achievement in kindergarten and first grade. *Educ Stat Q*. 2002;4(1):19-26.
8. Kamil ML, Mosenthal PB, Pearson PD, Barr R, eds. *Handbook of Reading Research.* Vol 3. New York, NY: Routledge; 2009
9. Snow CE, Burns MS, Griffin P, eds. *Preventing Reading Difficulties in Young Children*. Washington, DC: National Academies Press; 1998. doi:10.17226/6023
10. Logue ME. Early childhood learning standards: Tools for promoting social and academic success in kindergarten. *Child Sch*. 2007;29(1):35-43. doi:10.1093/cs/29.1.35
11. Kaiser AP, Cai X, Hancock TB, Foster EM. Teacher-reported behavior problems and language delays in boys and girls enrolled in Head Start. *Behav Disord*. 2002;28(1):23-39. http://www.jstor.org/stable/23889147. Accessed September 1, 2016.
12. Schulting AB, Malone PS, Dodge KA. The effect of school-based kindergarten transition policies and practices on child academic

outcomes. *Dev Psychol*. 2005;41(6):860-871. doi:10.1037/0012-1649.41.6.860

13. Chambers B, Cheung A, Slavin RE, Smith D, Laurenzano M. Effective early childhood education programs: A systematic review. Center for Research and Reform in Education. http://files.eric.ed.gov/fulltext/ED527643.pdf. Published 2010. Accessed September 1, 2016.
14. Morris A. *Effectiveness of Early Childhood Education Programs on the Literacy Learning of Children from Low Socioeconomic Status Background* [master's thesis]. Brockport, NY: The College of Brockport: State University of New York; 2015. http://digitalcommons.brockport.edu/cgi/viewcontent.cgi?article=1588&context=ehd_theses. Accessed September 1, 2016.
15. Klein L, Knitzer J. *Effective Preschool Curricula and Teaching Strategies, Pathways to Early School Success, Issue Brief No. 2.* National Center for Children in Poverty. http://files.eric.ed.gov/fulltext/ED522728.pdf. Published September 2006. Accessed September 1, 2016.
16. National Association for the Education of Young Children, National Council of Teachers of Mathematics. Early childhood mathematics: Promoting good beginnings. National Association for the Education of Young Children. http://www.naeyc.org/files/naeyc/file/positions/psmath.pdf. Updated 2010. Accessed September 1, 2016.
17. Mandel Morrow L, Gambrell LB, eds. *Best Practices in Literacy Instruction*. 4th ed. New York, NY: Guilford Press; 2011.
18. Ko C-H, Chou M-J. Aesthetics in early childhood education: The combination of technology instruments in children's music, visual arts and pretend play. *J Soc Sci*. 2014;10(1):39-45. doi:10.3844/jssp.2014.39.45
19. Parette HP, Quesenberry AC, Blum C. Missing the boat with technology usage in early childhood settings: A 21st century view of developmentally appropriate practice. *Early Child Educ J*. 2010;37(5):335-343. doi:10.1007/s10643-009-0352-x
20. Rosen DB, Jaruszewicz C. Developmentally appropriate technology use and early childhood teacher education. *J Early Child Teacher Educ*. 2009;30(2):162-171. doi:10.1080/10901020902886511
21. Copple C, Bredekamp S, eds. *Developmentally Appropriate Practice in Early Childhood Programs Serving Children from Birth through Age 8*. 3rd ed. National Association for the Education of Young Children. https://www.naeyc.org/files/naeyc/file/positions/position%20statement%20Web.pdf. Published 2009. Accessed September 1, 2016.

22. National Association for the Education of Young Children, Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College. Technology and interactive media as tools in early childhood programs serving children from birth through age 8. http://www.naeyc.org/files/naeyc/file/positions/PS_technology_WEB2.pdf. Published January 2012. Accessed September 1, 2016.
23. Council on Communications and Media. Media and young minds. *Pediatrics*. 2016;138(5):e20162591.
24. Council on Communications and Media. Media use in school-aged children and adolescents. *Pediatrics*. 2016;138(5):e20162592.
25. Freeman NK, Somerindyke J. Social play at the computer: Preschoolers scaffold and support peers' computer competence. *Inf Technol Child Educ Ann*. 2001;2001(1):203-213.
26. Heft TM, Swaminathan S. The effects of computers on the social behavior of preschoolers. *J Res Child Educ*. 2002;16(2):162-74. doi:10.1080/02568540209594982
27. Clements DH, Sarama J. Strip mining for gold: Research and policy in educational technology—A response to "Fool's Gold." *AACE J*. 2003;11(1): 7-69. https://www.learntechlib.org/p/17793. Accessed September 1, 2016.
28. Clements DH, Sarama J. Young children and technology: What *does* the research say? *Young Child*. 2003;58(6):34-40. http://www-cache.pbskids.org/island/brochure/powerpoint/Clements_Young_Children.pdf. Accessed September 1, 2016.
29. Greenfield PM. Developmental considerations for determining appropriate Internet use guidelines for children and adolescents. *Appl Dev Psychol*. 2004;25(6):751-62. doi:10.1016/j.appdev.2004.09.008
30. Kirkorian HL, Wartella EA, Anderson DR. Media and young children's learning. *Future Child*. 2008;18(1):39-61. www.princeton.edu/futureofchildren/publications/docs/18_01_03.pdf. Accessed September 1, 2016.
31. Adams MJ. *Technology for Developing Children's Language and Literacy: Bringing Speech Recognition to the Classroom.* The Joan Ganz Cooney Center at Sesame Workshop. http://joanganzcooneycenter.org/Reports-30.html. Published September 21, 2011. Accessed September 1, 2016.
32. What Works Clearinghouse™. *Procedures and Standards Handbook*. Version 3.0. http://ies.ed.gov/ncee/wwc/Docs/referenceresources/wwc_procedures_v3_0_standards_handbook.pdf. Published March 2014. Accessed September 1, 2016.

33. Cheung ACK, Slavin RE. The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educ Res Rev*. 2013;9:88-113. doi:10.1016/ j.edurev.2013.01.001
34. Cheung ACK, Slavin RE. The effectiveness of education technology for enhancing reading achievement: A meta-analysis. Center for Research and Reform in Education. www.bestevidence.org/word/tech_read_April_25_2012.pdf. Published May 2011. Accessed September 1, 2016.
35. Slavin RE, Lake C. Effective programs in elementary mathematics: A best-evidence synthesis. *Rev Educ Res*. 2008;78(3):427-515. doi:10. 3102/0034654308317473
36. Kulik JA. Effects of using instructional technology in elementary and secondary schools: What controlled evaluation studies say. SRI International. http://downloads.kennisnet.nl/mediawijzer/Onderzoeken/Kulik_ITinK-12_Main_Report.pdf. Published May 2003. Accessed December 21, 2016.
37. Blok H, Oostdam R, Otter ME, Overmaat M. Computer-assisted instruction in support of beginning reading instruction: A review. *Rev Educ Res*. 2002;72(1):101-130. doi:10.3102/00346543072001101
38. Raudenbush SW. The *Brown* legacy and the O'Connor challenge: Transforming schools in the images of children's potential. *Educ Res*. 2009;38(3):169-180. doi:10.3102/0013189X09334840
39. Brooks-Gunn J. Do you believe in magic? What we can expect from early childhood intervention programs. *Soc Res Child Dev*. 2003;17(1):3-14. http://srcd.org/sites/default/files/documents/spr17-1.pdf. Accessed September 1, 2016.
40. Zeh JD, Baenen NR. *Early Prevention of School Failure: Evaluation Report*. Wake County (NC) Public School System. http://files.eric.ed.gov/fulltext/ED351097.pdf. Published August 1991. Accessed September 1, 2016.
41. Renaissance Learning. *The Research Foundation for STAR Assessments™: The Science of STAR*. http://doc.renlearn.com/KMNet/R003957507GG2170.pdf. Published 2014. Accessed September 1, 2016.
42. Classworks. Design and validity of summative benchmark assessments. http://www.classworks.com/uploads/research/ResearchBasis2012_Benchmark.pdf. Updated January 8, 2013. Accessed September 1, 2016.
43. Good R, Kaminski R, Shinn M, et al. Technical adequacy of DIBELS: Results of the Early Childhood Research Institute on measuring growth and development. University of Oregon. 2004.

https://dibels.uoregon.edu/docs/techreports/DIBELS_Technical_Adequacy_TR07.pdf. Published 2004. Accessed September 1, 2016.