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EFFECTS OF EDUCATIONAL TECHNOLOGY ON MATHEMATICS ACHIEVEMENT FOR K-12 STUDENTS IN UTAH

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Teaching mathematics has long required the use of technology due many powerful affordances. More recently, education technology has been developed to support personalized learning through the use of adaptive learning systems. Through the use of educational technology in online learning, there is great potential for improving students' mathematics achievement. In this article, we report the results of an evaluation study, where 11 online mathematics educational technology products were distributed to close to 200,000 K-12 students and their teachers in the state of Utah to supplement classroom instruction. While only ten percent of students used the products at the recommended level over the course of the 2014-15 school year, there were six products where an educationally meaningful impact on mathematics achievement was found. While teachers responded positively, a third of teachers reported lack of access to technology as a barrier. We are already seeing improved usage during the second year of the project due to modifications to the expectations for schools based on what was learned from the first year of implementation.

INTRODUCTION

Education technology shows great potential for facilitating mathematics instruction and improving students' mathematics learning outcomes (Cheung & Slavin, 2013). In this article, we report the results of an evaluation study, where 11 mathematics educational technology products were distributed to close to 200,000 K-12 students and their teachers in the state of Utah. These products were to be used as supplements to regular classroom instruction and were not intended to replace the instruction by teachers. In particular, we report students' usage of these products over the course of the 2014-15 school year, discuss the findings of the impact of these mathematics products on students' achievement on the state assessment, and describe teachers' feedback about using these products. We also discuss the scientific and practical significance of this project and how it might inform future research and similar projects across the nation where technology is being scaled across a large group of teachers and their students.

BACKGROUND

Teaching mathematics has long required the use of technology due to the educational benefits afforded by such technology (National Council of Teachers of Mathematics., 2011). In recent years, educational technology has provided many features that enable it to support individualized instruction and personalized learning (e.g., adaptive learning system). Specifically, these kinds of products provide each student with different learning content (e.g., adaptive quiz and real-time feedback) and curriculum by collecting and analyzing each student's data so that each student can learn mathematics at their own pace. These technologies are being used as effective supplements for teachers, allowing them to monitor each student's progress and current state of mathematics performance. To realize these advantages and to improve their students' mathematics achievement, many school districts have been increasing their spending on educational technology (Richard & Sarabeth, 2016).

The more that students use educational technology to learn, and the more that schools invest in such technology products, the more precisely the assessment of the effects of such technology is needed. To date, a substantial number of studies have attempted to examine the effectiveness of educational technology on student achievement in mathematics (see Cheung & Slavin, 2013; Slavin, Lake, & Groff, 2009). Most recently, De Witte, Haelermans, and Rogge (2015) found a positive effect of computer-assisted instructional programs on learning outcomes in mathematics for secondary students. However, Cheung and Slavin (2013) argue that the effects could vary depending on technology type and usage intensity. Therefore, more research is constantly needed to assess the effects of technology products rigorously.

Preparing and supporting teachers to integrate technology effectively is also important in maximizing the effect of implementing new technology (Lawless & Pellegrino, 2007; Niess, 2005; Thomas & Palmer, 2014). Indeed, the roles and knowledge of teachers in technology-rich classrooms are much different than they used to be in the traditional classroom (Trigueros, Lozano, & Sandoval, 2014). For example, when students learn using a mathematics software program, they might need their teacher's assistance in order to properly interpret the feedback they receive from the program (Abboud-Blanchard, 2014). For adequate training and sufficient support for mathematics teachers, it is essential to identify what factors exist that make it difficult or easy for teachers to use technology to teach mathematics.

Prior research has discovered different types of factors that may influence the successful integration of technology. Hew and Brush (2007) have identified the following six main barriers to technology integration for K-12 classrooms from forty-eight empirical studies: lack of resources (40%), lack of knowledge and skills (23%), the institution (14%), teacher beliefs and attitudes (13%), student assessment (5%), and subject culture (2%). Lack of resources, a barrier mentioned most frequently in this study, includes several sub-categories, such as lack of technology, limited access to technology, lack of time, and limited technical support (Hew & Brush, 2007). Even though the lack of sufficient resources has long been a main obstacle to the effective integration of technology into teaching and has been considered a barrier that is easier to eliminate (Ertmer, 1999), it continues to be a significant hindrance today (Carver, 2016).

Previous research has also demonstrated that teachers' attitudes toward and beliefs about the educational benefits of technology comprise another key factor in achieving the more frequent use of technology in classrooms (Domingo & Garganté, 2016; Inan & Lowther, 2010; Kim, Kim, Lee, Spector, & DeMeester, 2013; Petko, 2012; Yuen & Ma, 2008). The theoretical background of these studies is based on the Technology Acceptance Model (TAM), which suggests that a user's willingness to use new technology increases when the user perceives that the new technology is easy to use and is useful (Davis, 1989). Through a qualitative survey of 68 K-12 teachers, Carver (2016) found that the majority of the responding teachers (82%) reported that the use of technology increased student engagement and student understanding.

Prior studies, however, have explored mainly teacher perception about a wide variety of technology devices (e.g., computer, handheld device, video project, camera, etc.) used in their classrooms, rather than focusing on personalized, adaptive learning software. Each device could be utilized differently for teaching and learning depending on its own attributes and the characteristics of the subject matter. Moreover, the recent work of Howard, Chan, and Caputi (2015) has confirmed that teachers' beliefs about technology integration differs between subject areas (e.g., English, mathematics, and science). Therefore, more research is needed to identify how teachers incorporate digital learning software into their classrooms, specifically when the software is designed for personalized learning and especially when such software is used in a particular subject area, such as mathematics.

INTERVENTION

Through funding from House Bill (HB) 139 legislation in Utah, the STEM Action Center was put into place in the Governor's Office of Economic Development. The mission of the STEM Action Center is to promote STEM best practices in education with a focus on Utah STEM industry connections. Through funding from HB 139 (2013) and HB 150 (2014), the Utah state legislature appropriated $13.5 million for mathematics software for K-12 students for the 2014-15 and 2015-16 academic years. In summer 2014, the STEM Action Center released a request for proposals (RFP) for providers of K-12 mathematics technology programs that provide a system that is adaptive and personalized to meet individual student needs, provides real time reporting to teachers and students, provides supports to address student needs, and a minimal amount of professional development or training focused on how to use the product and reporting features. In Table 1, we provide a list of the 11 products selected through the RFP process, the product provider/vendor, and the grade levels in which they were implemented.

In general, the products selected were intended to cover the curriculum for a particular grade level, with some flexibility to allow students to access below and above grade level curriculum with the exception of three products: EdReady, Reflex, and ST Math. EdReady is a program that is primarily used to assess a student's readiness for college level mathematics. Once the assessment is completed and areas of weakness are highlighted, the student can use curriculum available within the program or use other curriculum provided by their teacher to address these identified areas of need. Reflex is a program that is used to develop mathematics fact fluency, such as addition and multiplication facts. ST Math is a completely visual spatial program with no oral or written language. It does not cover some grade level curriculum standards, such as geometry, but focuses on foundational conceptual understanding of number (whole numbers, decimals, and fractions) and operations. It also has the breadth of exposing students to algebra. All of these products were intended to be used as supplements to the core mathematics curriculum.

Table 1
Overview of the Mathematics Products and Their Providers

Product name	Provider name	Grade Levels Implemented
ALEKS®	McGraw-Hill	3 – 12
Catchup Math	Hotmath, Inc.	6 – 12
Cognitive Tutor®	Carnegie Learning	9 – 12
EdReady®	NROC Project	9 – 12
i-Ready®	Curriculum Associates	K – 8
MathXL®	Pearson NCS	9 – 12
Odyssey Math®	Compass Learning	6 – 8
Reflex®	Explore Learning	6 – 8
ST Math®	MIND Research	K – 8
SuccessMaker®	Pearson NCS	K – 5
Think Through Math®	Think Through Learning	K – 8

Due to a delay in contract negotiations, SuccessMaker was not implemented during the 2014-15 academic year. While licenses for Odyssey Math were distributed, the teachers did not believe it was appropriate for their students and decided to not implement the product.

PURPOSE AND RESEARCH QUESTIONS

The purpose of this evaluation was to examine the impact of different mathematics technology products on students' achievement and to understand teachers' experiences implementing these products. This study addresses the following questions:

1. What is the impact of supplemental use of mathematics educational technology on student proficiency on the state assessment?
2. What common themes do teachers report from the implementation of the educational technology in their classrooms?

METHODS

Study Design

The most rigorous research design for estimating the impact of a program would be to randomly assign either schools, teachers, or students to use the products or to continue business-as-usual (BAU) practices. Such studies allow one to make the strongest causal statements regarding the impacts of an intervention or program. However, in this case, random assignment was not feasible, since the goal of this legislatively funded project was to reach as many students as possible and not to add on additional constraints that might prevent some districts or schools from participating.

Therefore, to answer the first research questions, the impact is estimated through a quasi-experimental approach using propensity-score matching (PSM). In PSM, a comparison group is formed by matching individual students using the technology on a one-to-one basis to students who most-closely resemble these students in the BAU group. This is the next best approach when random assignment is not feasible.

To answer the second research question, we collected qualitative self-report data through surveys of teachers participating in the grant program. Classroom observations were not conducted due to the cost associated with collecting that type of information.

Data Collection

We collected monthly usage data from the providers to understand implementation during the year. At the end of the year, we asked the providers to determine a benchmark for what was termed "fidelity of implementation," a recommended amount of usage or level of mastery that they would expect to be associated with student achievement gains. In this way, we were able to see which students met this benchmark and determine if there was a greater impact for these students. Each product provider determined what represented fidelity (recommended usage) for their product (see Table 2).

Table 2
Recommended Usage Benchmarks Set by Product Providers

Product	Grades	Description of Benchmark
ALEKS	K-5, 6-8, 9-12	Minimum of 480 minutes (8 hours)
Cognitive Tutor	9-12	An algorithm determined by the provider, not defined
EdReady	9-12	Not applicable *
Catchup Math	6-8, 9-12	An algorithm determined by the provider, not defined

Table 2, *Continued*

Product	Grades	Description of Benchmark
i-Ready	K-5, 6-8	30 minutes per week
Math XL	9-12	Not available
Odyssey Math	6-8	Not available
Reflex	6-8	An algorithm that includes fluency gains and average number of logins per week.
ST Math	K-5, 6-8	An algorithm based on content progress and/or lab logins that differed by grade.
SuccessMaker	K-5	Not available **
Think Through Math	K-5, 6-8	>20 lessons passed

Note. * "Not applicable" is noted for EdReady, because the teacher determines appropriate usage; therefore, no benchmark for recommended usage was provided. ** "Not available" is noted when providers did not set a benchmark for recommended usage.

To address the first question concerning the impact of these mathematics products, we received data from the Utah State Office of Education with the students in the grant program flagged and the rest of the students in the state to be used for comparison purposes. The de-identified data file we received contained the state achievement test (2014-15) scale score and proficiency level for mathematics, language arts, and science and other variables, such as unique student identifier, unique school identifier, school locale, student characteristics (gender, ethnicity, English Language Learner status, eligibility for free or reduced lunch, special education status), and prior achievement of each student on the state assessment (2013-14).

To address the second research question concerning teachers' feedback on these mathematics products, we developed a teacher survey to understand their satisfaction with the product, any concerns that they had with the product implementation, experience with the data reporting features, in addition to any other feedback they wanted to share. The survey included the following questions:

1. Please describe how you used the technology product in the last thirty days (e.g., as a supplement, as an intervention, selected materials for instruction, selected materials for homework).

2. Describe your overall satisfaction with the technology product.

3. Describe any technology or other barriers that prevented you from using the product with your students as much as you would have wanted to use the product.

4. Describe how you have been using any of the data reporting features of the product to understand your students' progress and/or to inform your instruction.

Qualtrics, an online survey platform, was used to administer the survey and automatically record teachers' responses.

Analytic Sample

By the end of the 2014-15 academic year, 196,625 licenses had been distributed to K-12 students. However, there were only 152,276 with evidence of usage. In Table 3, we provide a summary of license distribution and usage across the mathematics products. Differences in number of licenses distributed was based on the products requested in the district/school grant application. Across products, only nine percent of students met the recommended benchmark for usage as set by the provider (Table 3).

However, there were data from only 44,497 students used in our analysis, who had both the prior and current year assessment data. One reason for the reduced sample is that students in K-3 did not have a prior year baseline assessment, and many students in grades 11 and 12 had completed their required assessments. In addition, some parents choose to have their students opt out of taking the state assessment. These factors reduced the size of the sample in our analysis.

Table 3
License Distribution and Usage for the 2014-15 School Year

	Total Licenses Distributed						
Product	Students	Districts	Charters	Schools	Product Usage in May	Usage Percentage	Percent Meeting Fidelity Benchmark
ALEKS	106,530	26	27	299	77,766	73%	2%
Cognitive Tutor	917	3	0	3	782	85%	10%
Catchup Math	286	0	3	3	82	29%	67%
EdReady	498	4	1	7	498	100%	NA
i-Ready	17,389	12	6	74	15,322	88%	4%
MathXL	3,124	5	3	16	3,085	99%	NA
Reflex	4,378	5	3	20	3,421	78%	44%
ST Math	36,327	12	5	99	31,162	86%	16%
Think Through Math	27,176	8	4	94	20,158	74%	32%
Total	196,625	36	38	488	152,276	77%	9%

Note: Schools at times have used two products, therefore, the sum of the values for number of schools across products does not correspond to the total column value. NA=Not Available from the provider.

For three of the products there was insufficient student data to conduct an impact analysis: Cognitive Tutor, EdReady and Reflex. In Table 4, we report the sample sizes of the full sample and the fidelity sample if available for the remaining six products and the average usage information to address the first research question. The number of students in the fidelity sample is approximately ten percent of the students in the full sample.

Table 4
Sample Size and Usage for Full and Fidelity Analytic Samples

	Full Analytics Sample		Fidelity Analytic Sample	
Product	Number of Students	Average Usage	Number of Students	Average Usage
ALEKS	27,190	835 minutes	633	2,329 minutes
Catchup Math	254	86 minutes	32	474 minutes
i-Ready	3,981	302 minutes	190	1,317 minutes
MathXL	318	1,670 minutes	—	—
ST Math	5,858	20 lab logins	801	76 lab logins
Think Through Math	6,896	19 lessons	2,814	70 lessons
Total	44,497	—	4,470	—

The sample for the second research question included any teacher who completed a survey during the 2014-15 school year. We do not have information on how many total teachers participated in the grant program, since grants were awarded to districts and student licenses were distributed to schools. It was estimated that between 3,000 and 5,000 teachers were involved in the grant program. An overview of the number of teachers responding to the survey by product is in Table 5.

Table 5
Sample of Teachers Completing Survey by Product and Overall

Product	Number of Teachers Completing Survey
ALEKS	1,216
Cognitive Tutor	15
Catchup Math	5
EdReady	12
i-Ready	462

Table 5, *Continued*

Product	Number of Teachers Completing Survey
MathXL	60
Reflex	97
ST Math	830
Think Through Math	236
Total	2,933

Data Analysis

We conducted the impact analysis based on two analytic samples: the full sample of students including students with any evidence of product usage and the fidelity sample of students including students who met the recommended usage benchmark. We matched students in the grant program using mathematics educational technology and those from the comparison group (BAU) using the MatchIt package in R through propensity score matching. MatchIt is used for nonparametric approaches to making causal inferences. This approach selects matched samples from the original intervention and BAU groups on propensity scores, the likelihood that the student would be in the intervention group.

The data office of the state office of education recommended against combining scale score data across grades, due to differences in the construction of each assessment. Instead they recommended that we match students based on prior year assessment scale scores in groups by type of test (e.g., mathematics grade 3), and then use proficiency as the outcome, which allowed the combination of data across grades. Following this guidance, we used the nearest-neighbor matching algorithm with 1-to-1 matching for each test combination using the model: intervention ~ mathematics pretest scaled scores. We tested different approaches to matching (including some more complex models), but in the end we decided that our goal was to minimize pretest differences between the groups while using the same matching model for each grant for ease of interpretation and dissemination of the results to our stakeholders.

We merged the data sets across tests in order to analyze the impact of technology use on the proportion of students meeting proficiency, regardless of grade. We compared the students' characteristics and prior achievement by product to determine if there were any significant differences between groups. A t-test was used to compare continuous variables and a z-test of proportions was used for all dichotomous variables. For most products, the groups were equivalent on prior assessment scores, but some differences were observed in demographic characteristics (as shown in Table 6) which were controlled for in our impact analysis. However, for ease of reporting, due to our stakeholder audience, we used consistent models described next.

Table 6
Statistically Significant Baseline Differences

Product	Full Sample	Fidelity Sample
ALEKS	FRPL, SPED, WT, HSP	GDR, WT, HSP
Catchup Math	LAP, FRPL, SPED	—
i-Ready	FRPL, WT, HSP	ELL, HSP
MathXL	LAP	—
ST Math	LAP, FRPL, WT, HSP	LAP, FRPL, WT, HSP
Think Through Math	FRPL, SPED, HSP	FRPL, WT, HSP

Note: FRPL = Free/Reduced Price Lunch, LAP = Language Arts Proficiency, SPED = Special Education, ELL = English Language Learner, GDR = Gender, HSP = Hispanic, WT = White.

We conducted a logistic regression using proficiency on the mathematics posttest as a binary outcome variable. The predictors in the logistic regression model were the following student-level variables: intervention, eligibility for free or reduced price lunch, special education status, English Language Learner status, gender, and prior year proficiency level for mathematics and language arts state assessments. Proficiency levels were treated as categorical variables, where "1" was the lowest proficiency and "4" was the highest proficiency level. Standard errors were corrected for clustering of students within schools using bootstrapping with school ID as a stratum. The outcome, an odds ratio, indicates whether the impact is in favor of the group of students using the technology or the BAU group. The result explains that the group in favor is more likely to have met proficiency on the state assessment. We also include a Cox effect size, which can be used to compare to effect sizes which have been shown to be educationally meaningful in prior research, such as 0.16 found by the meta-analysis by Cheung and Slavin (2013).

For the second research question, we used open coding to develop codes and categorize teachers' survey responses (Strauss & Corbin, 1998). We report themes that emerged from the analysis along with exemplar statements for each theme. We coded the same feedback from teachers for each product. The teacher feedback is important, because it provides important insight into their experiences and can inform the work in future years of the project.

RESULTS

Impact Analysis

There were 44,497 students included in the analysis for the full sample of students with any amount of usage and 4,470 students in the fidelity sample of students who had met or exceeded the recommended level of usage. The results from logistic regression are provided in Table 7. We report odds ratio, standard error, *p*-value, effect size, and 95% confidence interval of the odds ratio for each product.

Table 7

Impact of Technology use on Achievement by Product

Product and Sample	Sample Size	Exp(B) odds ratio	Standard error[a]	Significatnce level	Effect Size	95% Confidence Interval for Exp(B) odds ratio: Lower	Upper
ALEKS							
Full Sample	27,190	1.014	0.026	0.607	0.01	0.964	1.067
Fidelity Sample	633	1.354	0.144	0.032	0.18	0.967	1.897
CatchUp Math							
Full Sample[b]	254	1.294	0.278	0.333	0.16	0.730	2.293
i-Ready							
Full Sample	3,981	0.983	0.063	0.804	-0.01	.861	1.122
Fidelity Sample	190	2.765	0.279	0.002	0.62	1.410	5.423
MathXL							
Full Sample[c]	318	1.464	0.317	0.078	0.23	0.821	2.611
ST Math							
Full Sample	5,858	1.125	0.126	0.296	0.07	0.910	1.390
Fidelity Sample	801	1.483	0.435	0.179	0.24	0.849	2.590
Think Through Math							
Full Sample	6,896	1.191	0.177	0.239	0.11	0.891	1.593
Fidelity Sample	2,814	1.339	0.235	0.097	0.18	0.952	1.884

aThe Standard Error and Significance have been adjusted for clustering.

bThere were only 32 students in the fidelity sample for Catchup Math, which was too small of sample to include in the analysis.

cThere was no fidelity sample for MathXL, because the product provider, Pearson, did not provide a fidelity benchmark.

When interpreting the odds ratio, values greater than 1.0 favor the students using the technology and anything less than 1.0 favors students in the comparison group. As can be seen from the odds ratio in Table 7, except for the i-Ready full sample, all other odds favor the students using the mathematics products, which implies that these products play a positive role in improving students' learning achievement or chances of meeting proficiency on the state assessment. The standard error and the related *p*-value of statistical significance are the values adjusted for clustering. There were only two products where the impact was statistically significant ($p <.05$), the fidelity samples for ALEKS and i-Ready, where students were using the products at the recommended level.

A *p*-value is influenced by sample size and variance in the sample. A researcher could have a really large sample and get a significant *p*-value, but the actual difference might not be very meaningful. Therefore, in research many are now using an effect size to better understand if there are meaningful differences. For mathematics educational technology, when used as a supplement to regular curriculum, prior research has shown the effect size to be around 0.16 (Cheung & Slavin, 2013). Therefore, we use 0.16 for the point of comparison to understand whether the impact of use of these products is educationally meaningful. We list the effect size information in Table 7. All six products included in the impact study, had at least one sample reach or exceed the 0.16 effect size level for having an effect on the proportion of students meeting proficiency on the state mathematics assessment.

Teacher Feedback

To address the second research question, we discuss the findings from our analysis of survey data from 2,933 teachers in the grant program. Feedback was provided for nine of the 11 products. We summarize the most frequent types of comments for each of the survey questions. The teachers were first asked to explain how they used the mathematics software products for their teaching. Overall, 56% reported supplemental use and 28% reported use as an intervention (as shown in Table 8).

There are some differences in use by product. For example, teachers using MathXL reported primarily assigning it as homework (53%). Reflex is a product specifically used for mathematics fact fluency, which is why it makes sense that 30% of teachers' reported the primary use as developing skill fluency. We did not gather more specifics on the ways in which teachers used the product as a supplement to instruction. In the second year of implementation, we are conducting site visits with interviews, focus groups, and classroom observations to better understand the supplemental use of these technology products to support mathematics instruction.

Table 8
Common Ways Teachers Used the Technology (Percent of Teachers)

Categories	Supplement to instruction	Intervention or Differentiation	Selected materials for homework	Practice for developing skill fluency	Review and re-teaching
ALEKS (N=1216)	49	26	16	6	10
Catchup Math (N=5)	40	40	0	0	0
Cognitive Tutor (N=15)	100	13	0	0	0
EdReady (N=12)	17	8	0	8	0
i-Ready (N=462)	47	42	8	4	1
MathXL (N=60)	25	8	53	3	0
Reflex (N=97)	34	24	30	29	19
ST Math (N=830)	70	23	13	10	5
Think Through Math (N=236)	75	36	13	15	9
Total (N=2,933)	56	28	15	8	7

For the second survey question, the teachers were asked to describe their overall satisfaction with the mathematics software. The teacher responses were coded for the primary focus or topic area of their response. We discuss only the most common five types of responses, therefore, the percentages across categories may not sum to 100%. Overall, 57% of the teachers reported overall general satisfaction (see Table 9). Many (11%) were satisfied with the way the product individualized instruction for the students. Ten percent reported being satisfied with student engagement while using the product.

The third survey question asked teachers about their concerns with the mathematics technology. There were very few negative comments about the technology products. Six percent of teachers reported technical difficulties with the program (Table 10). Cognitive Tutor was the product with the highest percent of negative responses where teachers reported student frustration.

However, it is important to note that the product and professional development package selected for this grant program was not the same package that Carnegie Learning usually provides for Cognitive Tutor implementation, but focused solely on the technology component for this implementation.

Table 9

Why Teachers Were Satisfied with Technology (Percent of Teachers)

Categories	Satisfied with provided technology	Learning is adaptive and individualized for students	Students are engaged when using technology	Develops students' knowledge or skills	Student success or positive experience
ALEKS (N=1,216)	59	16	3	3	5
Catchup Math (N=5)	0	20	20	0	20
Cognitive Tutor (N=15)	40	0	0	0	0
EdReady (N=12)	0	8	0	0	17
i-Ready (N=462)	20	7	6	1	2
MathXL (N=60)	53	8	2	0	2
Reflex (N=97)	62	6	20	20	6
ST Math (N=830)	77	5	18	9	7
Think Through Math (N=236)	52	19	22	17	8
Total (N=2,933)	57	11	10	6	5

Table 10
What Teachers Did Not Like about Technology (Percent of Teachers)

Categories	Product technical problems	Not used the technology yet	Student frustration or difficulty	Lack of challenge or boring to students	Need more time to use the product
ALEKS (N=1,216)	5	9	2	2	2
Catchup Math (N=5)	0	0	0	0	0
Cognitive Tutor (N=15)	7	0	13	0	7
EdReady (N=12)	0	0	0	0	0
i-Ready (N=462)	5	2	1	2	7
MathXL (N=60)	2	12	5	0	2
Reflex (N=97)	0	3	0	2	1
ST Math (N=830)	7	2	3	2	1
Think Through Math (N=236)	10	1	10	6	1
Total (N=2,933)	6	5	3	2	2

The fourth survey question asked teachers to report challenges with integrating these mathematics products into their class instruction. Thirty-two percent of teachers reported lack of technology access to be the greatest barrier (Table 11). The next most common challenge was in setting up student accounts, with the largest percent of teachers with concerns reported for MathXL (12%) and ST Math (10%).

Table 11
Challenges Reported for Technology Integration (Percent of Teachers)

Categories	No barriers	Not enough computers	Licenses, accounts, and setup	Lack of home access	No or little use
ALEKS (N=1,216)	37	31	2	4	4
Catchup Math (N=5)	60	40	0	0	0
Cognitive Tutor (N=15)	20	27	0	7	0
EdReady (N=12)	33	17	8	0	0
i-Ready (N=462)	29	29	3	2	4
MathXL (N=60)	37	22	12	7	0
Reflex (N=97)	48	25	0	8	3
ST Math (N=830)	30	37	10	3	3
Think Through Math (N=236)	32	30	6	7	4
Total (N=2,933)	34	32	5	4	4

The fifth survey question asked teachers how they used the performance management features of these mathematics products. The most common response was teachers reporting use of these features to monitor student progress (34%). Approximately 20% of teachers surveyed who used Catchup Math and i-Ready used these features for generating reports for student's Individualized Education Plans or to guide instruction for Response to Intervention (Table 12).

The data collection and reporting features are one of the primary strengths of these software programs; therefore, it was unfortunate to see so few teachers using these features to guide instruction and support for students (Table 12). In talking to teachers at a few participating schools we have learned that the first year they were focused more on logistics (e.g., access to computers) and this second year they have had time to plan for better integration and are beginning to find value in the data reports.

Table 12
Use of Performance Management Features (Percent of Teachers)

Categories	Monitor students' progress	Did not Use	Guide instruction	Used to determine product usage	Used for student IEP or RTI
ALEKS (N=1216)	31	21	15	17	4
Catchup Math (N=5)	20	0	0	40	20
Cognitive Tutor (N=15)	0	27	0	20	0
EdReady (N=12)	50	8	8	8	0
i-Ready (N=462)	29	1	9	1	19
MathXL (N=60)	35	8	12	12	10
Reflex (N=97)	57	3	4	9	5
ST Math (N=830)	31	38	11	4	9
Think Through Math (N=236)	61	4	9	6	12
Total (N=2,933)	34	20	12	10	9

LIMITATIONS

Prior research has shown many factors to be important for successful technology integration, such as the type of technology, the usage intensity, and different teacher factors. Studying the mediation effects of these factors was outside the scope of this study, since the purpose of this study was for accountability for the funding to determine overall impact on student achievement by product to inform future purchasing decisions. Future research can consider whether there are different types of technology with different affordances associated with differential effects on student achievement or if there is an interaction between teacher factors and usage and related effects on achievement.

A potential confound in the research design is that data was not collected on the types of mathematics technology software being used by students in the state in the comparison group. It may be that some were using very similar types of mathematics technology products, which may have reduced the ability to detect a significant effect of supplemental technology use on achievement.

Another limitation is that our logistic regression was conducted using original data, and did not screen for common support (Caliendo & Kopeinig, 2008) between treatment and comparison groups. We learned of this approach after the results had been presented to the stakeholders. We will consider this approach in year 2 when we will conduct a similar set of analyses with data from the second year of implementation.

Our survey data analysis was conduced over a short period of time (approximately two weeks) where eight graduate research assistants were involved in coding the open-ended teacher responses. Due to time constraints of needing to get the report to the stakeholders funding the project, we restricted our final analysis and summary of the data to the most common coding categories. If this area of research were our primary interest, we would have had multiple coders for each product data and have analyzed reliability among the coders. Therefore, the information we provide is for the purpose of context to note similarities in teacher feedback overall and by product.

CONCLUSIONS

We believe that these results from the first year of implementation of mathematics educational technology show the promise of these types of programs in providing individualized instruction, practice, and automatic feedback to students. Schools continue to be faced with pressures of accountability and the desire for all students to succeed. It is difficult to guarantee that all students will receive high quality instruction in mathematics each day. However, with technology students and their parents have access to mathematics instruction that can provide remediation and acceleration. Rather than turning in an assignment and having to wait several days for feedback, which may be just a mark noting correct/incorrect responses, students now can have access to prescriptive feedback highlighting the errors made with some products even providing a re-teaching experience.

Our findings are consistent with prior research, which has shown that teachers have challenges integrating technology into the classroom. Prior research has shown that infrastructure (Armstrong, 2014) can be a challenge to technology integration, which was confirmed by 32% of teachers responding to our survey who reported that they lacked sufficient access to technology.

While only 34% reported use of the performance management features of the products, it is not clear whether this relates to teachers' technical skills as reported by prior research to be a challenge (Ertmer, 1999) or whether it was not as high of a priority as logistical issues of setting up accounts, gaining access to computers, and learning the basics of the software in this first year.

While we find preliminary evidence to support impact of the technology on student achievement proficiency, this was in general when students were meeting the recommended level of usage. Of concern is that 90% of the students in the full sample were not meeting recommended usage. This may be due to the process of how this grant program ran through the district office, which may have slowed down distribution of licenses. This second year (2015-16) grants were limited to schools with usage during year 1, and the grant application required a letter of commitment from the school principal for access to technology for a minimum of 45 minutes per week for students using the educational technology. Mid-year the second year, close to 50% of students were meeting the recommended level of usage.

IMPLICATIONS FOR FUTURE RESEARCH AND PRACTICE

During this first year of implementation, teachers shared several different common models for integrating technology into the classroom. A model that seemed more common in elementary schools was the use of a technology station of four to six students with chrome books or computers for student use. This approach was reported as a way to differentiate instruction where the teacher could work with a small group, while stations were set up for students to rotate through independent work, with one station having the mathematics education technology. More common for middle school or junior high teachers was the use of computers on wheels (a rack of 25-30 computers) shared between teachers in a hall or section of the building or the use of a computer lab. Future research should consider differences in implementation by grade group.

The grant program restricted selection of products to one product per school with no child having access to more than one product. However, several schools have reported a concern that students may become bored using the same product for multiple years and have requested that future grants consider the option of using one product for grades K-3, another for grades 4-6, etc. Product developers can also consider options for development that keep a student engaged, such as allowing the student to select a different avatar or setting, since there is some prior research evidence to support the impact of allowing students to personalize their learning experience (Walkington, 2013). Future research can consider whether impact decreases over time with student fatigue or boredom with a particular platform.

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