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Promising Practices for Creating Strong Technology-Enabled Learning Environments: Associations Between Teachers' Math Learning Software Implementation Practices and Students' Mathematics Achievement

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THE UNIVERSITY OF UTAH
UTAH EDUCATION POLICY CENTER

Bridging Research, Policy, and Practice

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Background

Overview

In partnership with the Utah STEM Action Center and the Utah State Board of Education (USBE), the Utah Education Policy Center (UEPC) continues to be engaged in research on technology-enabled teaching and learning. To date, the UEPC has sought to:

- determine the impact of technology-enabled instruction on student learning in mathematics,
- better understand the contexts in which engagement with technology supports student learning in mathematics, and
- identify promising instructional practices of teachers who use technology to engage students in mathematics learning.

This report extends the UEPC's previous research by 1) empirically testing associations between specific math learning software implementation practices and student achievement outcomes, and 2) identifying factors that impact whether teachers engage in these promising instructional practices.

In this section of the report, we provide an overview of the relevant research literature, focusing on the role that technology-enabled instruction might play in addressing historical and pandemic-related underperformance in mathematics among K-12 students. Next, we summarize the UEPC's most recent work on technology-enabled instructional practices. Briefly, the UEPC's recent work in this area began in 2021-2022 with conversations with teachers identified as "positive outliers" in using learning software programs to support instruction in mathematics. Findings from these conversations along with a review of the extant literature on technology-enabled instruction were used to inform the development of surveys of teachers and students about their use of math learning software and attitudes toward technology, mathematics teaching, and mathematics learning. Survey data were, then, used to examine associations between math learning software use and teachers' adoption of personalized, competency based instructional strategies, students' adoption of growth mindsets, and teachers' perceptions of the value of math learning software. This work was a precursor to the findings presented in the current report which focuses on associations between teachers' math learning software implementation practices and student achievement outcomes.

Mathematics Performance Among K-12 Students

Students in the United States continue to struggle in mathematics (National Science Board and National Science Foundation, 2024; OECD, 2024). While there were modest improvements in math achievement test scores for K-12 students taking the NAEP assessment from 1990 to 2007, scores were stagnant from 2007 to 2019 and sharply declined following the pandemic-related closure of schools in March 2020 (U.S. Department of Education et al., 2024). Although there are some promising signs of a return to pre-pandemic performance in mathematics, researchers are estimating that full recovery, if attainable, may take years, especially for Black and Hispanic students and students attending high-poverty schools. These findings underscore pre-existing disparities in achievement and reveal that historically marginalized students have borne a disproportionate impact from the pandemic (Fahle, Kane, Reardon, & Staiger, 2024; Goldhaber, Kane, McEachin, Morton, Patterson, & Staiger, 2023; Kuhfeld & Lewis, 2022; Kuhfeld, Soland, & Lewis, 2022; Lewis & Kuhfeld, 2022; Lewis, Kuhfeld, Langi, Peters, & Fahle, 2022; Lewis & Kuhfeld, 2023).

In line with national trends, a report released by the Utah State Board of Education (USBE) also indicated significant learning loss due to pandemic-related disruptions. Specifically, analyses of student RISE and Utah Aspire Plus assessments showed lower math scores in 2020-2021 compared to 2018-2019, particularly among students who were economically disadvantaged (USBE and the National Center for the Improvement of Educational Assessment, Inc., 2021).[1] By 2023, only 27.1% of students who were economically disadvantaged were proficient in math compared to 45.1% of all students. This finding is concerning given the USBE's goals to raise math proficiency rates, especially among groups who have performed less well historically (USBE Strategic Plan Implementation Update, 2023).

Technology-Enabled Learning Environments

One strategy that has been proposed for addressing both underperformance and disparities in performance in mathematics is to create stronger, technology-enabled learning environments (Ertmer & Ottenbreit-Leftwich, 2013; Huebner & Burstein, 2023). Consistent with this strategy, in May 2023, the National Council of Teachers of Mathematics (NCTM) released a position statement on the Equitable Integration of Technology for Mathematics Learning. In this statement, the NCTM argues that "technology should be used to develop and deepen learning understanding, stimulate interest in the mathematics being learned, and increase mathematical proficiency" (NCTM, 2023, p. 1). At the same time, the NCTM indicates that more needs to be done to ensure that "technology is used strategically" to provide "more equitable access and opportunities for each and every learner to actively engage and participate in the learning of mathematics" (NCTM, 2023, p. 1).

The set of technologies considered by the NCTM and by others interested in technology-enabled learning environments is broad. Examples of these technologies include learning software programs, Learning Management Systems (LMS), online course platforms, and Virtual Reality (VR) and Augment Reality (AR) systems. In the current study, we focus on math learning software programs that are designed to supplement traditional instruction by offering students interactive lessons, tutorials, practice exercises, and/or assessments. A key feature of many of these learning programs is that they are "personalized" and "adaptive," meaning that they continuously adjust tasks, instructions, or feedback as students work to master new skills (Baker, 2016a). As such, these programs hold promise for supporting teachers in meeting the learning needs of heterogeneous groups of students (Bernacki, Greene, & Lobczowski, 2021).

In the United States, use of math learning software programs has been linked to positive achievement outcomes for students, including stronger scores on summative assessments and more positive achievement-related attitudes (e.g., Cheung & Slavin, 2013; Kulik & Fletcher, 2015). Similar results have been reported in Utah, where research conducted by the Utah Education Policy Center (UEPC) on students' access to and use of math learning software programs has demonstrated that students who use math learning software programs that have been selected for inclusion in the Utah STEM Action Center's K-12 Math Personalized Learning Software Grant Program[2] are more likely to be proficient in mathematics, to demonstrate growth in mathematics, and to hold growth mindsets than non-users, especially when usage levels are high (e.g., Altermatt, Altermatt, Rorrer, & Moore, 2022; Altermatt, Rorrer, Altermatt, Doane, & Timmer, 2023b; Su, Rorrer, Owens, Pecsok, Moore, & Ni, 2020). Importantly, however, the impact of math learning software on achievement outcomes appears to be moderated by a variety of factors including the intensity and quality of use (Altermatt, Rorrer, Altermatt, Doane, & Timmer, 2023c; Pane, Steiner, Baird, Hamilton, & Pane, 2017; Valadez & Duran, 2007; U.S. Department of Education, 2012; Zheng, Long, Zhong, & Gyasi, 2022).

[1] RISE and Utah Aspire Plus assessments were not administered in 2019-2020 because of the Covid-19 pandemic.

[2] https://stem.utah.gov/educators/funding/k-12-math-personalized-learning-software-grant/

The conclusion that the effectiveness of math learning software differs across contexts is consistent with findings from a recent study conducted by the UEPC in Utah. Here, we examined associations between mean monthly minutes of math learning software use at the classroom level and student achievement at the classroom level as measured by student growth percentiles (SGPs) on a statewide math assessment for the six math learning software programs selected for inclusion in the STEM Action Center's K-12 Math Personalized Learning Software Grant Program. Representative results from one software program are presented in Figure 1. These results indicate that, although the relationship between usage and achievement is generally positive, it is also modest, with considerable variability across educators (Altermatt, Rorrer, & Moore, 2022).

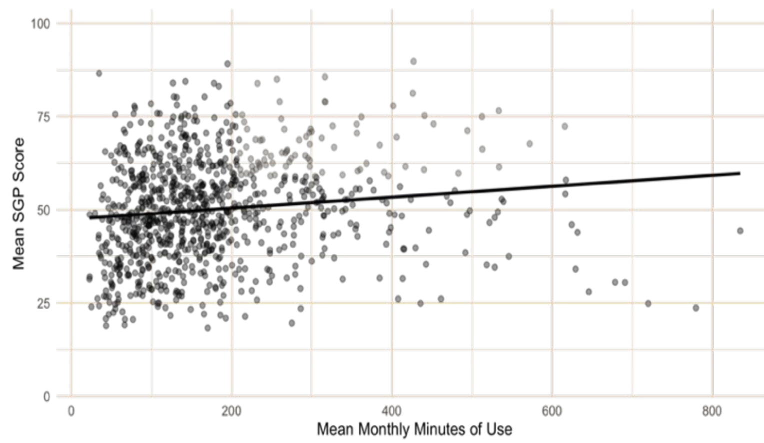


Figure 1. Scatterplot of mean monthly minutes of use by mean student growth percentile (SGP) score for educators using one math learning software program in 4th – 8th grade classrooms. Source: Altermatt, Rorrer, & Moore (2022).

More research is needed to understand the specific pedagogical strategies teachers use when implementing math learning software in their classrooms, including the goals teachers' set for students' software use and the degree to which they attend to and use software-provided learning analytics data. There is also a pressing need to empirically examine which implementation strategies yield the most favorable outcomes for students.

Meta-analytic reviews have been helpful in providing initial insights into the reasons why math learning software use is associated with such disparate outcomes. For example, learning software appears to be more effective when educators are provided training on how to use the software and when software is used as a supplement to instruction rather than as a replacement (Hillmayr, Ziernwald, Reinhold, Hofer, & Reiss, 2020). However, much more research is needed to understand the specific pedagogical strategies teachers use when implementing math learning software in their classrooms, including the goals teachers' set for students' software use and the degree to which they attend to and use software-provided learning analytics data. There is also a pressing need to empirically examine which implementation strategies yield the most favorable outcomes for students (Huebner & Burstein, 2023; Van Schoors, Elen, Raes, Vanbecelaere, & Depaepe, 2023).

Previous Findings from UEPC Implementation Studies in Utah

Over a three-year period, the UEPC has partnered with Utah's STEM Action Center and with the USBE to conduct a series of studies aimed at understanding best practices for creating strong technology-enabled learning environments in mathematics in Utah. A brief history of this research, along with a summary of key findings from Year 1 and Year 2, is presented here, followed by an overview of the current (Year 3) study.

Year 1

In 2021-2022, the UEPC began its exploration of promising practices for math software implementation by identifying educators who, over a three-year period, were in the top 25% of educators in the state on *both* a metric of software engagement (i.e., mean number of minutes students in their classrooms used the software each month) and a metric of achievement (e.g., mean student growth percentile). These "positive outliers" and other educators were invited to participate in data-gathering sessions at the STEM Best Practices Conference hosted by the STEM Action Center in June 2022.

Data gathered from these educators combined with a review of a still-nascent literature on technology-enabled learning environments (see Huebner & Burstein, 2023, for a review) yielded a number of potentially impactful implementation practices for math learning software including: 1) using software as a support for evidence-based teaching practices rather than as a replacement, 2) setting clear, mastery-based goals for software use, and 3) using data from math learning software programs to inform and personalize teaching in real-time. Results from this study and from a complementary study on math learning software use during the Covid-19 pandemic were presented in two UEPC reports released in Summer 2022 (Altermatt, Altermatt, Rorrer, & Moore, 2022; Altermatt, Rorrer, & Moore, 2022).

Year 2

In 2022-2023, the UEPC drew upon findings from the Year 1 data-gathering sessions and its review of the extant literature to construct a survey for teachers to assess their general instructional strategies in math, strategies for implementing math learning software, perceptions of math learning software, and self-efficacy for teaching mathematics. With support from the USBE, the UEPC distributed email invitations to complete the teacher survey to 16,923 K – 6th grade teachers and 7th – 12th grade math teachers Utah in March 2023. Importantly, the survey was *not* limited to teachers who were participating the STEM Action Center's K-12 Math Personalized Learning Software Grant Program. This was intentional as it allowed the UEPC to gather data from teachers with a wide variety of experiences with math learning software programs, including teachers who were not using *any* math learning software program and those who were using math learning software via licenses provided by other entities (e.g., USBE, LEAs). Year 2 analyses focused on analyses of both teacher and student survey data.

Among the key findings from Year 2 efforts were the following:

1. Utah students were more likely to report that math learning software had value when they used the software frequently and when they perceived high levels of alignment with classroom instruction (Altermatt, Rorrer, Altermatt, Doane, & Timmer, 2023b).

2. Utah teachers were less likely to report setting mastery-based goals for their students' use of math software than time-based goals. However, mastery-based goal setting was more strongly associated with positive teacher perceptions of the value of math software and with students' endorsement of growth mindsets. Associations between goal setting and outcomes were especially strong among teachers who reported providing lower levels of support to students as they used software (Altermatt, Rorrer, Altermatt, Doane, & Timmer, 2023c).

Full results from Year 2 efforts were presented in a UEPC report that provided descriptive statistics for all items included on both teacher and student surveys (Altermatt, Timmer, Doane, Altermatt, & Rorrer, 2023) and three UEPC research briefs (Altermatt, Rorrer, Altermatt, Doane, & Timmer, 2023a, 2023b, and 2023c).

Overview of the Current Study

Methods and Research Questions

In Year 3 (2023-2024) of the UEPC's current program of research related to technology-enabled learning, teacher survey responses were examined alongside of teacher demographic data, student demographic data, and student achievement data (e.g., RISE Math scales scores)[3] to address two central research questions:

1. What teaching strategies emerge as "promising practices" for math learning software implementation by virtue of predicting positive student achievement outcomes in mathematics?
2. What factors impact whether teachers engage in these "promising practices" for math learning software implementation?

Given evidence that students who are economically disadvantaged in Utah are performing less well than their more affluent peers in mathematics (e.g., USBE, 2023) and that "schools that are better-resourced and serve students from more privileged backgrounds tend to use technologies in more innovative ways" than schools that are more poorly resourced and serve economically-disadvantaged students (Holstein & Doroudi, 2021, p. 5), we included the percentage of students who qualify for free and reduced-price lunch (FRPL) in the school as a key predictor in analyses designed to answer both research questions. In doing so, we were able to determine whether differences exist in the effectiveness and/or the use of particular implementation strategies across settings. For Research Question 2, we also examined whether the extent to which teachers engaged in promising practices for math learning software implementation differed across a range of teacher-level predictors including years of teaching experience, years of experience using software, and grade level.

Analytic Sample

A description of the teacher survey – including methods for survey development and administration, response rates, and descriptive statistics for each item – is provided in Altermatt, Timmer, Doane, Altermatt, & Rorrer (2023; see also Pane et al., 2017). The report has been shared with the STEM Action Center and with the USBE, and it is available on the UEPC website. The analytic sample for the current study included the subset of teachers who consented to participate, indicated that they taught math, completed the survey using a personalized survey link, reported using math learning software, taught grades 3 - 8, and had at least 5 students with scale scores from RISE Math end-of-year assessments. This resulted in a dataset with 38,016 students linked to 841 teachers.

Report Organization

The remainder of this report is organized into four sections.

- In the first section, we focus on Research Question #1, with the goal of identifying promising practices for math learning software implementation. We begin with a summary of analysis

[3] The Utah Education Policy Center has a Master Data Sharing Agreement with the Utah State Board of Education, which permits use of education data for evaluation and research purposes. Importantly, the UEPC adheres to terms of the Master Data Sharing Agreement, including terms of use, confidentiality and non-disclosure, data security, monitoring, and applicable laws. The UEPC also complies with University of Utah Institutional Review Board policies for educational research and evaluation. Though the UEPC is housed at the University of Utah, only authorized UEPC staff may access the data, and data are not available throughout the University or to other parties. The views expressed in this report are those of UEPC staff and do not necessarily reflect the views or positions of the USBE or the University of Utah.

procedures, followed by a summary of findings. Detailed findings follow, organized around five broad sets of implementation practices (e.g., the extent to which teachers set goals for their students' use of math software).

- In the second section, we focus on Research Question #2, with the goal of examining how teacher-level factors (e.g., years of teaching experience) and school-level factors (i.e., percentage of students who qualify for free and reduced-price lunch) impact the degree to which teachers engage in promising practices for math learning software implementation. We begin with a summary of analysis procedures, followed by a summary of findings. Detailed findings follow, organized around the six promising implementation practices that emerged from analyses for Research Question #1.
- In the third section, we provide a discussion of key findings and offer considerations for math learning software implementation across the state.
- Finally, we provide a developer- and practitioner-friendly infographic highlighting "promising practices" for math learning software implementation.[4]

[4] The layout for this infographic was inspired by work completed by Promise54.org.

Research Question #1.
What teaching strategies emerge as "promising practices" for math learning software implementation by virtue of predicting positive student achievement outcomes in mathematics?

Summary of Analyses

Because students were nested within teachers, random-intercepts multilevel modeling (MLM) was used to examine associations between teachers' self-reported math learning software implementation practices and students' achievement growth in mathematics.[5] In all models, the **outcome variable** was 2023 RISE Math test scale scores, standardized within grade-level. In each model, we included the following **predictors:**

- students' prior year math proficiency as determined by scores on the 2022 RISE Math test,
- teachers' self-reported number of years of math teaching experience,
- the percentage of students in the school who qualified for free and reduced-price lunch (FRPL),
- one or more of the following software implementation strategies – assessed at the classroom level – as reported by teachers, organized into five sets, including,
  - **minutes of math learning software use** per week,
  - **context of math learning software use** (e.g., whole class instruction vs. independent work),
  - **goal-setting for math learning software use** (e.g., time goals vs. mastery goals),
  - **viewing math learning software data** (e.g., viewing data on students' performance on specific skills vs. data on students' time using software),
  - **use of math learning software data** (e.g., using data to adapt course pacing vs. to discuss learning with students), and
- the two-way interaction between each implementation practice and the percentage of students in the school who qualify for FRPL.

All continuous variables were standardized. By including multiple practices in each model, we were able to examine the independent effect of each practice. By including two-way interactions, we were also able to determine whether the impact of each implementation practice varied across schools serving students differing in levels of economic advantage.

Summary of Findings

- Prior year math proficiency and teachers' self-reported number of years of math teaching experience were both strong, positive predictors of 2023 RISE Math scores.
- In contrast, the percentage of students in the school who qualified for free and reduced-price lunch (FRPL) was a strong negative predictor of students' 2023 RISE Math scores.
- Six math learning software implementation strategies emerged as **"promising practices,"** as they positively predicted gains in math scale scores. The practices are summarized in the textbox. Details are provided in the pages that follow. The effect of each of these "promising practices" for implementation was generally similar across schools serving both high and low percentages of students who qualified for FRPL.

Promising Practices

1. Select evidence-based math learning software to support teaching and learning.
2. Use math learning software to support teachers or tutors in providing individual instruction to students.
3. Set mastery goals for students' use of math learning software.
4. Be attentive to data from math learning software about student performance on specific skills.
5. Use data from math learning software to identify areas for strengthening teacher knowledge or skills.
6. Use data from math learning software to reflect on and discuss learning with students.

[5] https://ies.ed.gov/ncee/edlabs/regions/northeast/pdf/rel_2015046.pdf

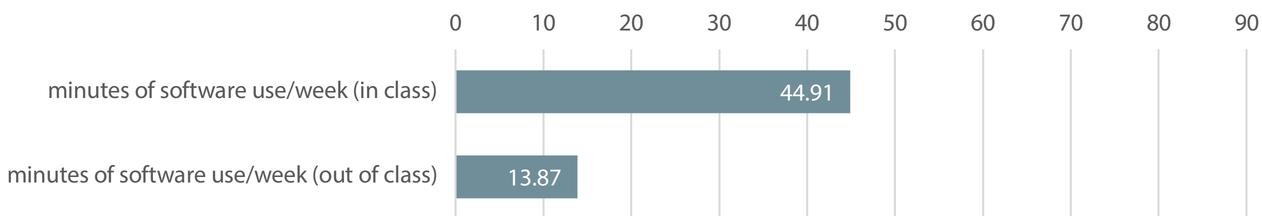
Minutes of Math Learning Software Use

Teachers were asked to indicate which software program they used most frequently and to report the average number of minutes students used the program both in class and outside of the classroom during a "typical" week. The majority of teachers (71.2%) reported that their "most used" program was one of six programs (ALEKS, DreamBox, i-Ready, Imagine Math, Mathspace, and ST Math) selected for inclusion in the K-12 Math Personalized Learning Software Grant program at the time the implementation survey was administered.[6]

How much are students using math learning software?

On average, teachers reported that their students used math learning software for ~60 minutes during a "typical" week. Teacher reports indicated that roughly three-quarters of total software use occurred in class.

Figure 1. Mean responses for items assessing frequency of math software use



What is the relationship between teacher-reported minutes of software use and test scores?

The results of multilevel modeling indicated that more frequent use of math learning software as reported by teachers was associated with stronger gains in math scores, but only when analyses were restricted to teachers who reported using one of the six software programs selected by the STEM Action Center for inclusion in the K-12 Math Personalized Learning Software Grant program.

Table 1. Results from MLM predicting math scores from the frequency of math software use

	RISE Math scale score			
	All Programs		Selected Programs	
Predictors	*t* - score	*p* - value	*t* - score	*p* - value
1. prior year math proficiency	206.61	.000***	162.12	.000***
2. years of math teaching	3.80	.000***	3.91	.000***
3. % of students who qualify for FRPL	-6.21	.000***	-4.87	.000***
4. minutes of use/week (total)	1.52	.128	2.18	.034*

* $p < .05$. *** $p < .001$.

Promising Practice #1. Select evidence-based math software to support teaching and learning.

Note. The two-way interaction between minutes of use and the percentage of students in the school who qualify for free and reduced-price lunch was also included in the model. The interaction is not included in the table as it was not statistically significant.

[6] These six software programs were selected by virtue of demonstrating effectiveness in improving student outcomes in mathematics in quasi-experimental studies conducted by the UEPC. Importantly, licenses for these programs are provided not only by the STEM Action Center, but by other entities including LEAs and the Utah State Board of Education.

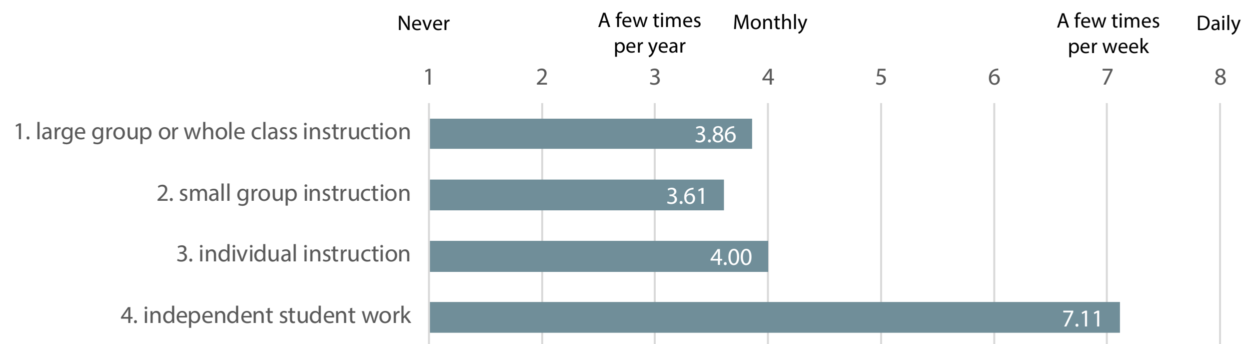
Context of Math Learning Software Use

Teachers were asked to indicate the frequency with which they used math software in four contexts: for large group or whole class instruction, for small group instruction, to support individual instruction with a student, or for independent student work. Teachers responded to all items on an eight-point scale that ranged from 1 (“never”) to 8 (“daily”).

In what contexts are students using math software?

> Teachers reported that they used math software for large group or whole class instruction, small group instruction, or individual instruction infrequently, between “a few times a year” and “monthly.” In contrast, teachers reported using software for independent student work “a few times per week” to “daily.”

Figure 2. Mean responses for items assessing the contexts in which teachers use math software



What is the relationship between context of software use and test scores?

> The results of multilevel modeling indicated that using software to support teachers or tutors in providing individual instruction to students was associated with stronger gains in math scores.

Table 2. Results from MLM predicting math scores from the contexts in which teachers use math software

	RISE Math scale score	
Predictors	*t* - score	*p* - value
prior year math proficiency	195.35	.000***
years of math teaching	3.03	.003***
% of students who qualify for FRPL	-5.69	.000***
1. large group or whole class instruction	-0.45	.653
2. small group instruction	-0.50	.615
3. individual instruction	2.04	.041*
4. independent student work	-1.36	.176

> Promising Practice #2. Use math software to support individual instruction with students.

* $p < .05$. *** $p < .001$.

Note. Two-way interactions between each implementation practice and the percentage of students in the school who qualify for FRPL were also included in the model. The interactions are not included in the table as none were statistically significant.

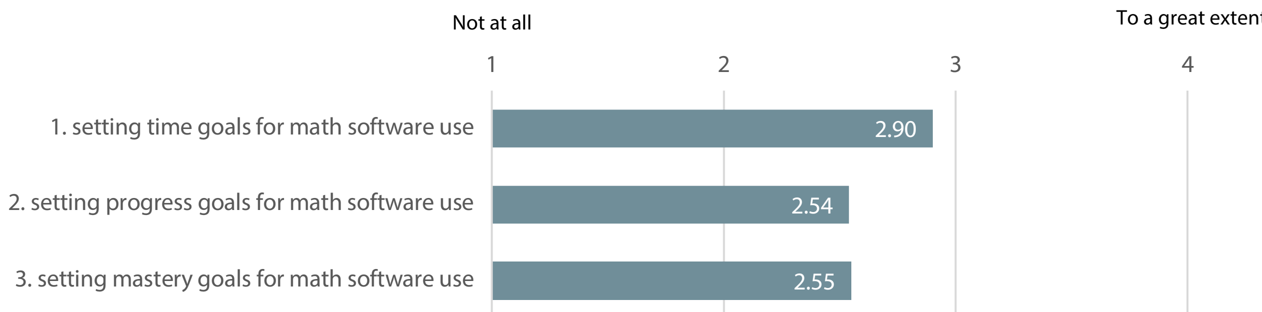
Goal-Setting for Math Learning Software

Teachers were asked to indicate the extent to which they require students to "spend a certain amount of time using math software" (a time goal), "get through a certain amount of material (e.g., units)" (a progress goal), and "demonstrate mastery of a certain number of concepts, topics, or skills when using math software" (a mastery goal). Teachers responded to all three items on a four-point scale that ranged from 1 ("not at all") to 4 ("to a great extent").

To what extent are teachers setting goals for software use?

> Teachers reported setting time goals for their students' use of software to a greater extent than setting either progress goals or mastery goals.

Figure 3. Mean responses for items assessing the extent to which teachers set goals for math software use



What is the relationship between teacher goal-setting for software use and test scores?

> The results of multilevel modeling indicated that setting mastery goals for students' use of software was associated with stronger gains in math scores. In contrast, setting time goals for students' use of software was associated with weaker gains in math scores.

Table 3. Results from MLM predicting math scores from the extent to which teachers set goals for math software use

	RISE Math scale score	
Predictors	*t* - score	*p* - value
prior year math proficiency	199.33	.000***
years of math teaching	3.21	.001***
% of students who qualify for FRPL	-5.53	.000***
1. setting time goals for math software use	-2.64	.009**
2. setting progress goals for math software use	0.09	.928
3. setting mastery goals for math software use	2.67	.008**

** $p < .01$. *** $p < .001$.

> Promising Practice #3. Set mastery goals for students' use of math software.

Note. Two-way interactions between each implementation practice and the percentage of students in the school who qualify for FRPL were also included in the model. The interactions are not included in the table as none were statistically significant.

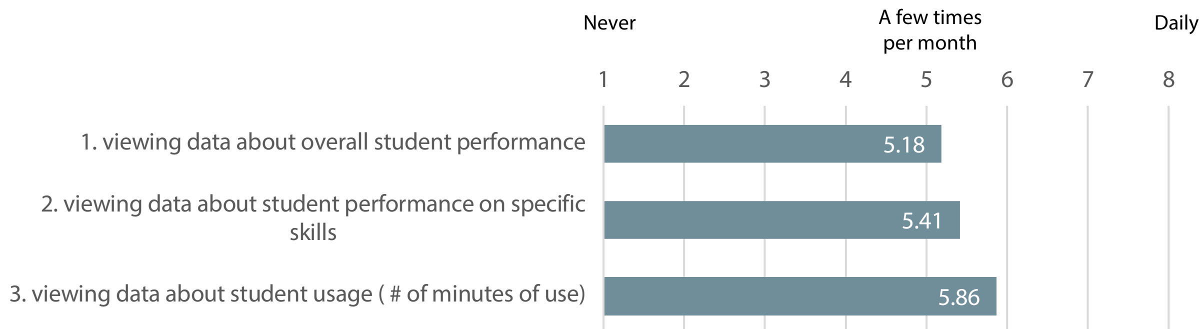
Viewing Math Learning Software Data

Teachers were asked to report on the frequency with which they viewed data from math software about student performance (i.e., overall and on specific topics or skills) and math software use (i.e., minutes of use). Teachers responded to each item on an 8-point scale ranging from 1 (“never”) to 8 (“daily”). Teachers were also given the opportunity to indicate that the software they used did not provide these data or that they did not know how to access these data. Between 4.8% and 5.9% of respondents in the full sample selected this option.

How frequently are teachers viewing math software data?

Teachers reported viewing data about student usage (i.e., # of minutes of use) somewhat more frequently than data about either overall student performance or student performance in specific areas. In all three cases, teachers reported viewing math software data between “a few times per month” and “weekly.”

Figure 4. Mean responses for items assessing the frequency with which teachers view math software data



What is the relationship between viewing math software data and test scores?

The results of multilevel modeling revealed that viewing data about student performance on specific topics or skills was associated with stronger gains in math scores. The effect of viewing data about student usage (# of minutes of use) differed by the % of students who qualify for FRPL in the school.

Table 4. Results from MLM predicting math scores from the extent to which teachers view math software data

	RISE Math scale score	
Predictors	*t* - score	*p* - value
prior year math proficiency	184.93	.000***
years of math teaching	2.33	.020*
% of students who qualify for FRPL	-5.88	.000***
1. viewing data about overall student performance	-1.56	.119
2. viewing data about student performance on specific skills	3.03	.003***
3. viewing data about student usage (# of minutes of use)	-1.90	.058
viewing data about student usage * % of students who qualify for FRPL	2.01	.044*

Promising Practice #4. Be attentive to data about student performance on specific skills.

* $p < .05$. *** $p < .001$.

Note. Two-way interactions between each implementation practice and the percentage of students in the school who qualify for free and reduced-price lunch were also included in the model. The one statistically significant interaction is included in the table and is explored on the following page.

To further explore the interaction between viewing data about student usage and the percentage of students in the school who qualify for free and reduced-price lunch, we divided the sample into two groups with a median split: **economically advantaged schools** (i.e., schools with fewer than 30% of students who qualify for free and reduced-price lunch) and **economically disadvantaged schools** (i.e., schools with greater than 30% of students who qualify for free and reduced-price lunch).

Results of multilevel models indicated that the effect of viewing data about student usage (# of minutes of use) differed by the percentage of students in the school who qualify for free and reduced-price lunch. Viewing data about student usage was negatively related to student achievement outcomes in economically advantaged schools, but unrelated to student achievement outcomes in math in economically disadvantaged schools. These analyses also revealed that the positive relationship between viewing data about performance on specific skills was largely driven by the effect in economically advantaged schools.

Table 5. Results from MLM predicting math scores from the extent to which teachers view math software data and the percentage of students in the school who qualify for free and reduced-price lunch

	RISE Math scale score			
	Economically advantaged schools		Economically disadvantaged school	
Predictors	*t* - score	*p* - value	*t* - score	*p* - value
prior year math proficiency	155.57	.000***	101.33	.000***
years of math teaching	1.26	.210	2.62	.009**
1. viewing data about overall student performance	-1.08	.280	-0.89	.374
2. viewing data about performance on specific topics	3.03	.003***	0.90	.369
3. viewing data about student usage (# of minutes of use)	-2.51	.013*	-0.23	.818

* $p < .05$. ** $p < .01$. *** $p < .001$.

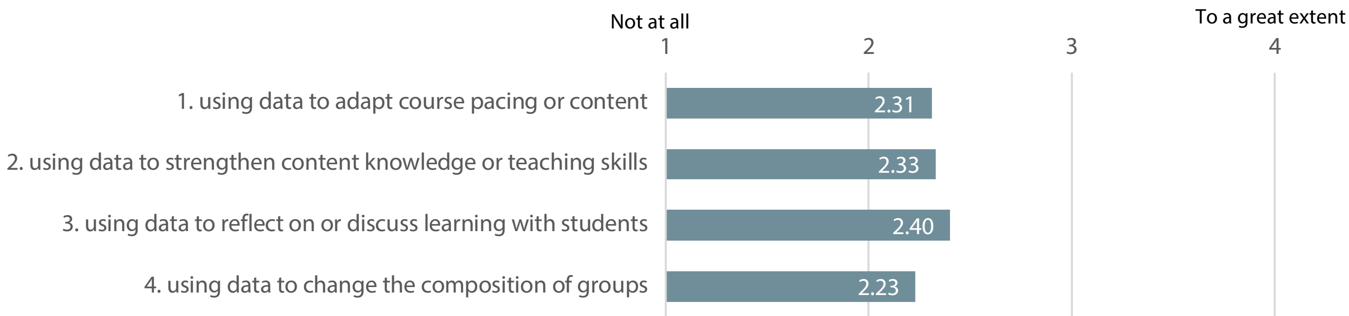
Use of Math Learning Software Data

Teachers were asked to indicate the extent to which they used data from math software to inform their instructional practices. Teachers responded to each item on a 4-point scale ranging from 1 ("not at all") to 4 ("to a great extent"). Teachers were also given the opportunity to indicate that they never engage in a particular activity (e.g., that they never change the composition of groups). Across items, between 14.3% and 27.3% of respondents in the full sample selected this option.

How frequently are teachers using math software data to inform instruction practices?

Teachers reported using data from math software to reflect on and discuss learning with students somewhat more frequently than using data for other purposes. However, ratings of all four types of data use were below the midpoint of the scale, suggesting relatively low levels of data use.

Figure 5. Mean responses for items assessing the extent to which teachers use data from math software



What is the relationship between using data and test scores?

Results of multilevel models indicated that using data to identify areas to strengthen teachers' content knowledge or teaching skills or to discuss learning with students was associated with stronger gains in math scores.

Table 6. Results from MLM predicting math from the extent to which teachers use data from math software

	RISE Math scale score	
Predictors	*t* - score	*p* - value
prior year math proficiency	159.74	.000***
years of math teaching	3.24	.001**
% of students who qualify for FRPL	-4.89	.000***
1. using data to adapt course pacing or content	-2.06	.040*
2. using data to strengthen teacher knowledge or skills	2.44	.015*
3. using data to reflect on or discuss learning with students	1.96	.050*
4. using data to change the composition of groups	-1.66	.098

* $p < .05$. ** $p < .01$. *** $p < .001$.

Promising Practices #5 & #6. Use math software data to identify areas for strengthening teachers' knowledge or skills and to discuss and reflect on learning with students.

Note. Two-way interactions between each implementation practice and the percentage of students in the school who qualify for FRPL were also included in the model. The interactions are not included in the table as none were statistically significant.

Research Question #2.
What Factors Impact Whether Teachers Engage in These "Promising Practices" for Math Learning Software Implementation?

Summary of Analyses

In our first set of analyses, six implementation strategies emerged as "promising practices" for math learning software implementation, as they positively predicted students' scores on statewide math assessments, controlling for prior performance and other covariates. In our second set of analyses, we ran six linear regression models to examine factors that might impact whether teachers engage in these practices. In each of the six models, the **outcome variable** was the software implementation practice. All models included the following **predictors:**

- a continuous variable representing teachers' self-reported number of years of math teaching experience,
- a continuous variable representing teachers' self-reported number of years using their current math learning software program,
- a dichotomous variable representing whether the teachers had earned an advanced degree (1 = yes),
- a dichotomous variable indicating whether the teacher was teaching at the secondary level (1 = yes),
- a continuous variable representing the percentage of students in the school qualifying for free and reduced-price lunch.

In addition, statistical models examining Promising Practices #2 - #6 included teacher-reported frequency of math software use at the classroom level.

Summary of Findings

Table 7 provides a summary of statistically significant findings across the six promising practices identified in analyses addressing Research Question 1. In the table, plus signs indicate statistically significant, positive associations between promising practices and teacher/school characteristics. Minus signs indicate statistically significant, negative associations between promising practices and teacher/school characteristics. For example, teachers with more years of math learning software use were more likely to set mastery goals for students' use of math software, while teachers teaching in a school with a high percentage of students who qualify for free and reduced-price lunch were less likely to do so.

Table 7. Summary of regression analyses predicting promising practices from teacher and school characteristics

Teacher and School Characteristics	PP #1 Select evidence-based math software to support teaching and learning	PP #2 Use math software to support individual instruction with students	PP #3 Set mastery goals for students' use of math software	PP#4 Be attentive to data for math software about student performance on specific skills	PP#5 Use math software data to identify areas for strengthening teacher knowledge or skills	PP#6 Use math software data to reflect on or discuss learning with students
More years of math teaching experience						
More years of math learning software use			+			+
Holding an advanced degree	+					

Teaching at the secondary level	+	+		+		
Using software for more minutes/week		+	+	+	+	+
Teaching in a school with a high % of students qualifying for FRPL			–			
Teaching in a school with a high % of students qualifying for FRPL when teacher has limited experience using math software		–			–	–

Promising Practice #1. Select evidence-based math software to support teaching and learning

Results of linear regression analyses indicated that teachers were more likely to frequently use math learning software selected by the STEM Action Center for inclusion in the K-12 Math Personalized Learning Software Grant Program when they held an advanced degree and when they taught at the secondary level.

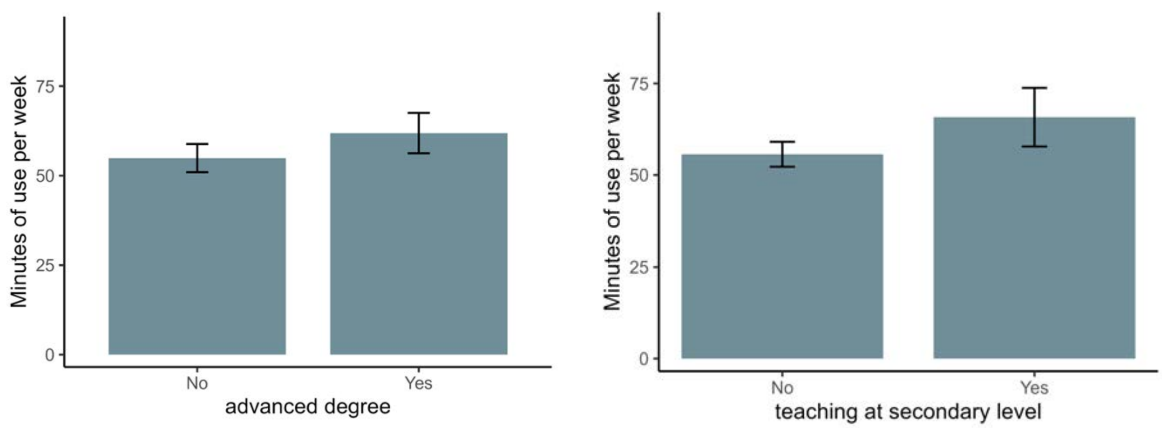
Table 8. Summary of regression analysis predicting frequency of "selected" math software use[7]

Predictors	Promising Practice #1	
	t - score	*p* - value
years of math teaching	-0.40	.688
years of math learning software use	1.35	.177
advanced degree (1 = yes)	1.96	.050*
secondary teacher (1 = yes)	2.28	.023*
% of students who qualify for FRPL	1.35	.176
% of students who qualify for FRPL * years of math learning software use	-1.51	.133

* $p < .05$.

Figure 6. Estimated marginal means examining the effect of having an advanced degree (a) and teaching at the secondary level (b) on minutes of "selected" math software use

(a) (b)



[7] As described on p. 14, teachers were asked to indicate which software program they used most frequently and to report the average number of minutes students used the program both in class and outside of the classroom during a "typical" week. Most teachers (71.2%) reported that their "most used" program was one of six programs (ALEKS, DreamBox, i-Ready, Imagine Math, Mathspace, and ST Math) selected for inclusion in the K-12 Math Personalized Learning Software Grant program at the time the implementation survey was administered. These six software programs were selected by virtue of demonstrating effectiveness in improving student outcomes in mathematics in quasi-experimental studies conducted by the UEPC. Importantly, licenses for these programs are provided not only by the STEM Action Center, but by other entities including LEAs and the Utah State Board of Education.

Promising Practice #2. Use math software to support individual instruction with students

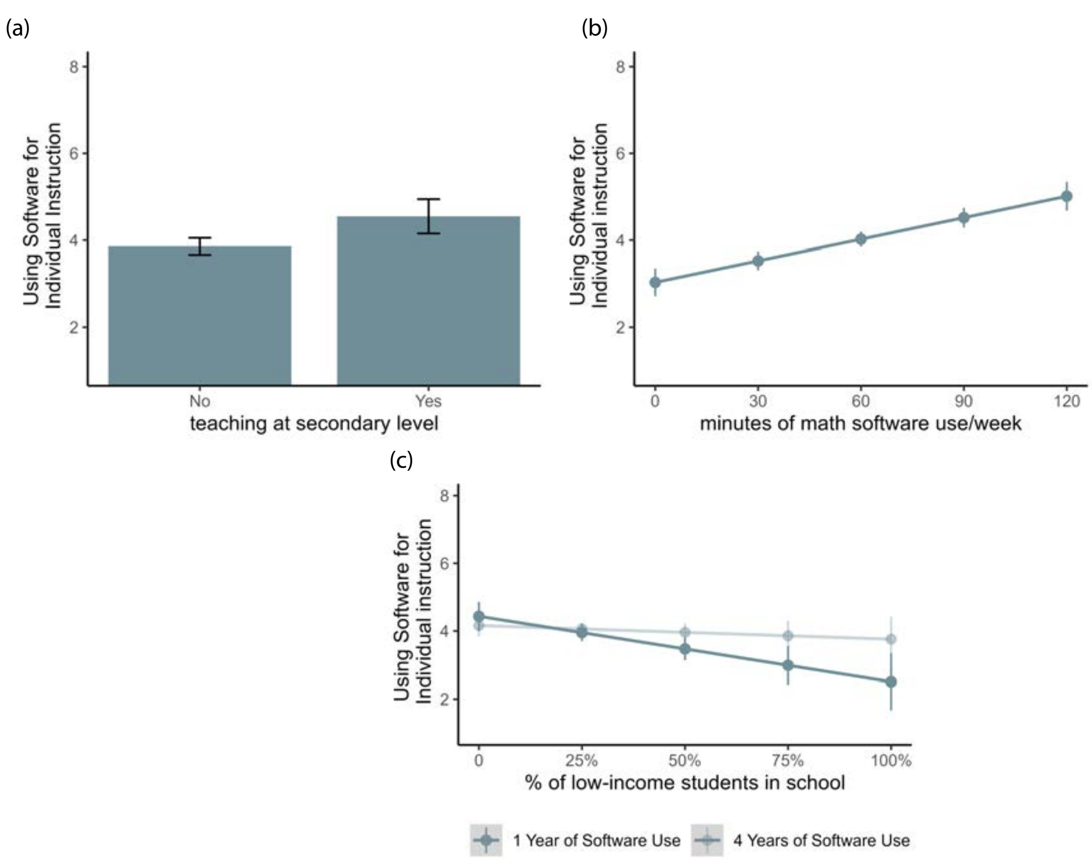
Results of linear regression analyses indicated that secondary math teachers and teachers whose students used the math learning program for more minutes per week were significantly more likely to use software to support teachers or tutors in providing individual instruction to students. In contrast, using software to support individual instruction with students was less common among teachers who taught in schools serving higher numbers of students who qualify for free and reduced-price lunch, especially when the number of years of math learning software use was low.

Table 9. Summary of regression analysis predicting frequency of using software to support individual instruction

Predictors	Promising Practice #2	
	t - score	*p* - value
years of math teaching	-0.58	.561
years of math learning software use	1.55	.121
advanced degree (1 = yes)	0.05	.959
secondary teacher (1 = yes)	3.06	.002**
minutes of math learning software use/week	7.06	.000***
% of students who qualify for FRPL	-1.91	.056^{+}
% of students who qualify for FRPL * years of math learning software use	2.75	.006**

$^{+}$ $p < .10$. ** $p < .01$. *** $p < .001$.

Figure 7. Estimated marginal means examining the effect of having teaching at the secondary level (a), minutes of math software use/week (b), and percentage of students in the school who qualify for FRPL (c) on using software to support individual instruction



Promising Practice #3. Set mastery goals for students' use of math software

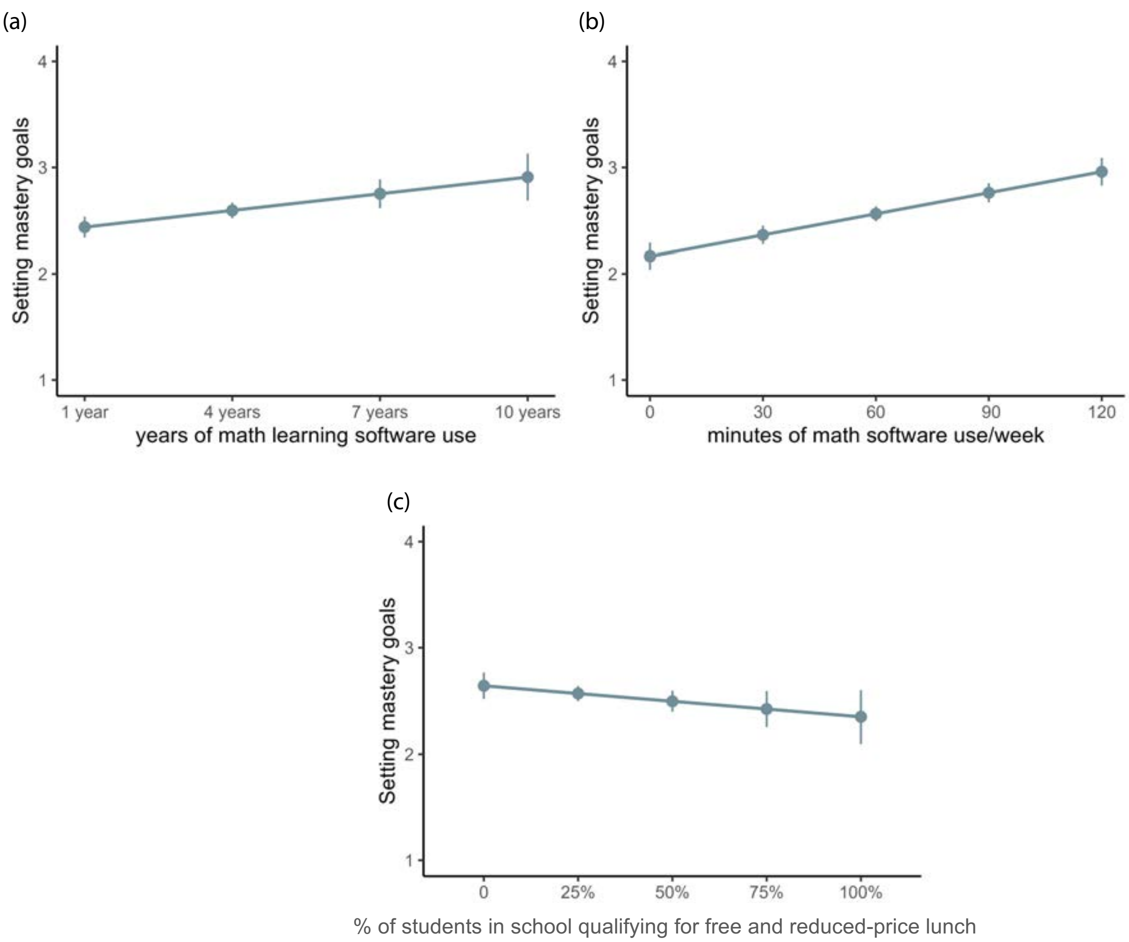
Results of linear regression analyses indicated that teachers with more years of experience using a math learning software program and whose students used the program for more minutes per week were more likely to set mastery goals for math software use. In contrast, mastery goal setting was less common among teachers who taught in schools serving higher numbers of students who qualify for free and reduced-price lunch.

Table 10. Summary of regression analysis predicting extent of setting mastery goals for math software use

	Promising Practice #3	
Predictors	*t* - score	*p* - value
years of math teaching	-1.55	.120
years of math learning software use	3.31	.000***
advanced degree (1 = yes)	-0.03	.980
secondary teacher (1 = yes)	0.22	.823
minutes of math learning software use/week	7.19	.000***
% of students who qualify for FRPL	-1.67	.095+
% of students who qualify for FRPL * years of math learning software use	0.32	.748

+ $p < .10$. *** $p < .001$.

Figure 8. Estimated marginal means examining the effect of years of math software use (a), minutes of math software use/week (b), and percentage of students in the school who qualify for FRPL (c) on setting mastery goals for math software use



Promising Practice #4. Be attentive to data about student performance on specific skills

> Results of linear regression analyses indicated that secondary teachers and teachers whose students used a math learning software program for more minutes per week were more likely to view data from math software about student performance on specific topics or skills.

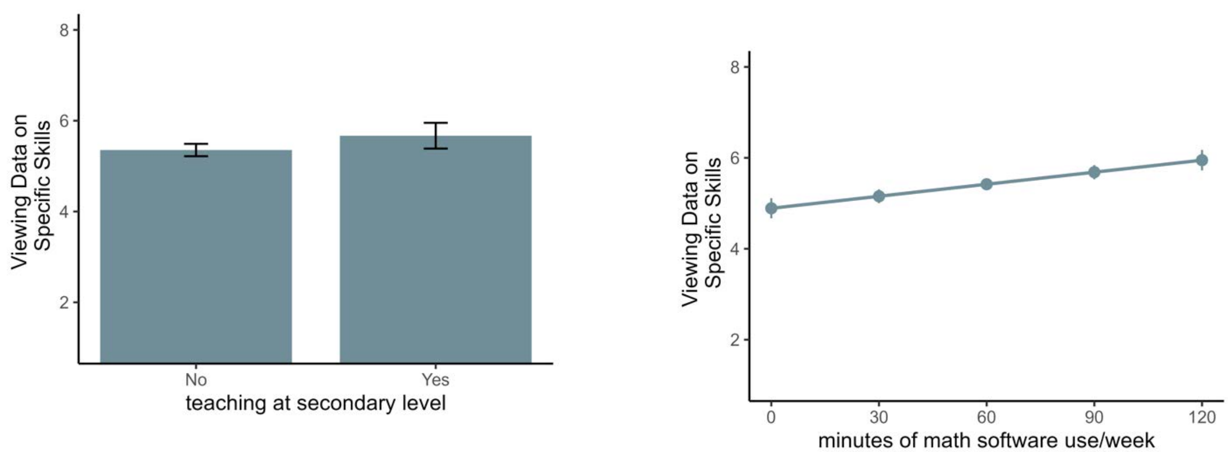
Table 11. Summary of regression analysis predicting frequency of viewing data on specific skills

	Promising Practice #4	
Predictors	*t* - score	*p* - value
years of math teaching	-1.58	.115
years of math learning software use	1.39	.195
advanced degree (1 = yes)	1.56	.120
secondary teacher (1 = yes)	1.96	.050*
minutes of math learning software use/week	5.57	.000***
% of students who qualify for FRPL	-0.24	.807
% of students who qualify for FRPL * years of math learning software use	0.73	.463

* $p < .05$. *** $p < .001$.

Figure 9. Estimated marginal means examining the effect of teaching at the secondary level (a) and minutes of math software use/week (b) on viewing data about student performance on specific skills

(a) (b)



Promising Practice #5. Use math software data to identify areas for strengthening teachers' content knowledge or teaching skills

Results of linear regression analyses indicated that teachers whose students used a math learning software program for more minutes per week were more likely to use math software data to identify areas for strengthening their own content knowledge or teaching skills. In contrast, using data for this purpose was less common among teachers who taught in schools serving higher numbers of students who qualify for free and reduced-price lunch, especially when the number of years teachers had used the math learning software was low.

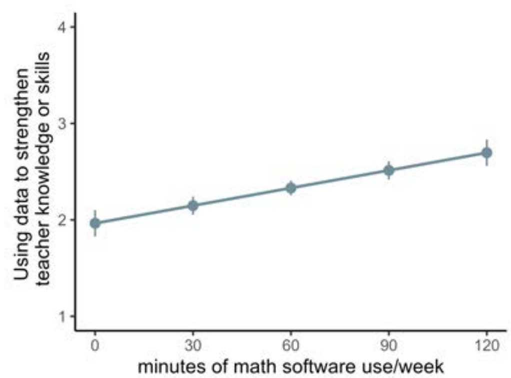
Table 12. Summary of regression analysis predicting extent of using data to strengthen content knowledge or teaching skills

Predictors	Promising Practice #5	
	t - score	*p* - value
years of math teaching	-0.71	.480
years of math learning software use	-0.02	.986
advanced degree (1 = yes)	1.48	.140
secondary teacher (1 = yes)	1.08	.281
minutes of math learning software use/week	6.28	.000***
% of students who qualify for FRPL	-1.76	.080+
% of students who qualify for FRPL * years of math learning software use	3.01	.003**

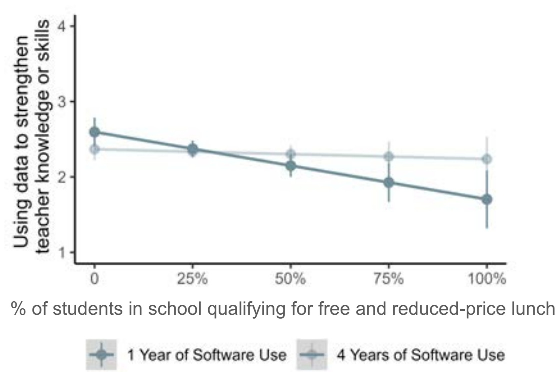
+ $p < .10$. *** $p < .001$.

Figure 10. Estimated marginal means examining the effect of minutes of math software use/week (a) and the interaction between percentage of students in the school who qualify for FRPL and years of math software use (b) on using math software data to identify areas for strengthening teachers' content knowledge or teaching skills

(a)



(b)



Promising Practice #6. Use math software data to reflect on and discuss learning with students

Results of linear regression analyses indicated that teachers whose students used a math learning software program for more minutes per week were more likely to use data to reflect on and discuss learning with students. In contrast, using data for this purpose was less common among teachers who taught in schools serving higher numbers of students who qualified for free and reduced-price lunch, especially when the number of years teachers had used the math learning software was low.

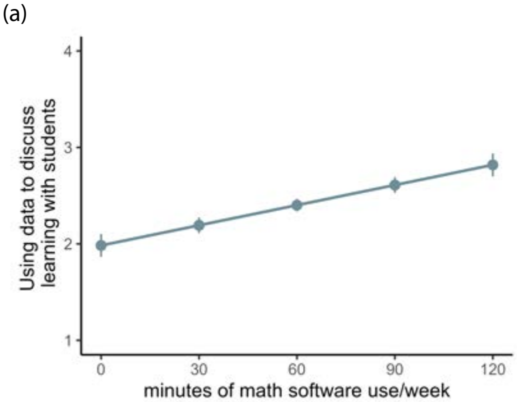
Table 13. Summary of regression analysis predicting extent of using data to reflect on and discuss learning with students

Predictors	Promising Practice #6	
	t - score	*p* - value
years of math teaching	-1.03	.306
years of math learning software use	2.44	.015*
advanced degree (1 = yes)	0.52	.604
secondary teacher (1 = yes)	0.33	.743
minutes of math learning software use/week	8.21	.000***
% of students who qualify for FRPL	-0.41	.608
% of students who qualify for FRPL * years of math learning software use	4.15	.000***

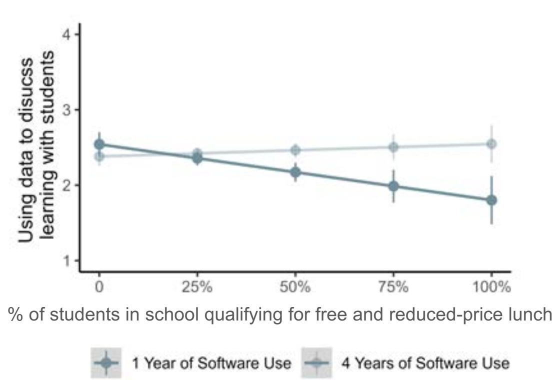
* $p < .05$. *** $p < .001$.

Figure 11. Estimated marginal means examining the effect of minutes of math software use/week (a) and the interaction between percentage of students in the school who qualify for FRPL and years of math software use (b) on using data to reflect on and discuss learning with students

(a)



(b)



Discussion

New Evidence on Strategies for Creating Effective Technology-Enabled Learning Environments

In 2013, Ertmer and Ottenbreit-Leftwich (2013) published a seminal paper that challenged educational researchers and practitioners to move away from the assumption that simply placing the "right" technology into classrooms would improve student outcomes. Two decades later, educational technology tools have improved considerably. Specifically, "personalized" and "adaptive" learning software programs are being developed that are capable of diagnosing students' understanding of a range of mathematical concepts, delivering content tailored to each student's particular level of knowledge, and offering immediate feedback, increasingly in ways that are attentive to students' affective states including boredom and frustration (Baker, 2016b; Baker, Boser, & Snow, 2022; Chung, Delacruz, Dionne, Baker, Lee, & Osmundson, 2016). Although these advances are promising, learning software systems that are currently being used at scale are still far from "intelligent" (Baker, 2016b). There remains a critical – and still unmet – need to understand and effectively equip teachers with the skills and knowledge they need to leverage existing educational technology tools to meaningfully impact teaching and learning and to adapt to new tools as they are developed.

> Simply placing the "right" educational technology into classrooms is insufficient for improving student learning outcomes in mathematics. There is a critical – and unmet – need to understand and effectively equip teachers with the skills and knowledge they need to leverage existing educational technology tools to meaningfully impact teaching and learning and to adapt to new tools – including AI-powered tools – as they are developed.

The current study sought to contribute to a nascent research and evaluation literature on technology-enabled instruction and learning as well as ongoing efforts to improve mathematics instruction in Utah by identifying "promising practices" for math learning software implementation. To this end, we examined associations between myriad software implementation practices and student achievement outcomes. These analyses revealed that students showed stronger gains in scores on statewide mathematics assessments when teachers:

1. selected evidence-based math learning software to support teaching and learning;
2. used math learning software to support teachers or tutors in providing individual instruction to students;
3. set mastery goals for students' use of math learning software;
4. were attentive to data from math learning software about student performance on specific skills;
5. used data from math learning software to identify areas for strengthening their own content knowledge or teaching skills; and
6. used data from math learning software to reflect on and discuss learning with students.

Our analyses indicated that these teaching strategies tended to be effective in schools serving both higher and lower percentages of economically-advantaged students. However, consistent with prior work indicating disparities in how educational technology is used across settings (Holstein & Doroudi, 2021; Rafalow & Puckett, 2022), several of these strategies were less common in schools with a high percentage of students who qualified for free and reduced-price lunch, especially when teachers had limited experience using the software. In contrast, these strategies tended to be more common at the secondary level, when teachers used the software for a greater number of years, and when students used the software for more minutes per week.

Considerations for Making Progress on Creating More Effective Technology-Enabled Learning Environments

Together with the results from the UEPC's earlier work on promising practices for creating strong technology-enabled learning environments (Altermatt et al., 2022; Altermatt et al., 2023a, 2023b, 2023c), the current study offers empirical evidence supporting the use of specific implementation strategies – including setting mastery goals for students' use of math software, being attentive to data about student performance on specific skills, and using data from software to strengthen instructional practices and to reflect on learning with students. Notably, none of these promising practices is especially common with, for example, teachers less likely to set mastery goals for students' use of math software (i.e., requiring students to demonstrate mastery of a certain number of skills) than time goals (i.e., requiring students to use the software for a certain number of minutes).

Although there is evidence that professional learning opportunities can play an important role in supporting teachers in creating strong, technology-enabled learning environments, these opportunities often fall short of achieving their intended aims (Huebner and Burstein, 2023). To ensure increased "uptake" of the promising practices identified in this report, educational leaders and practitioners in Utah might consider the following:

- Provide additional time for teachers to learn to use the math learning software programs they select or that are made available to them. As a group, teachers who completed the teacher survey and indicated that they used math learning software in 2022-2023 reported using their current math learning software program for a median length of time of two years. This may be insufficient to develop deep knowledge about how to utilize the software to support teaching and learning. Teachers need time to learn about the educational technology tools that they select or that are made available to them and to experiment with implementation strategies (Phillips, Pane, Reumann-Moore, & Shenbanjo, 2020). Teachers also need time to learn how to effectively access and use the learning analytics data that learning software programs provide to improve instruction (Baker, 2016a).

  Consistent with this conclusion, teachers who participated in the current study were more likely to set mastery goals for students' software use and more likely to use data to support individual instruction with students as the number of years of experience with a math learning software program increased. Moreover, while several "promising practices" for software implementation were less common in schools with high percentages of students who qualify for free and reduced-price lunch, this relationship largely disappeared among teachers who had used their current software for four or more years.

- Provide opportunities for both pre-service and in-service teachers to learn how to implement "promising practices" for creating strong technology-enabled environments that meet students' learning needs. Too often, professional learning opportunities for educational technology use are short-term and focused on the mechanics of using educational technology tools rather than on best practices for supporting strong technology-enabled instruction and learning. This type of short-term, mechanics-focused training approach is unlikely to be effective in changing long-standing professional practices or effectively leveraging technology for addressing student learning needs (Huebner & Burstein, 2023; Phillips et al., 2020). Instead, professional learning for math learning software should be attentive to the latest research on technology-enabled learning environments. For example, training should be attentive to new research from this and other studies that indicates that students may be most likely to benefit from technology-enabled learning environments when teachers or tutors are available (and have the data they need) to provide the motivational and relationship supports that many students require to persist when software use leads to boredom, frustration, or confusion (e.g., Baker, Hutt, Bosch, et al., 2023; Thomas, Lin, Gatz, et al., 2024). To be most effective, training should also: include ongoing coaching, incorporate opportunities to learn from peers, focus on skill development related to how to access and use available learning analytics data, and be evaluated in real-time for continuous improvement (Darling-Hammond, Zielezinski, & Goldman, 2014; Han, Byun, & Shin, 2018; Phillips et al., 2020; Xie, Nelson, Cheng, & Jiang, 2023).

Including additional training on technology-enabled learning environments for pre-service teachers will also be important. Many university-based preparation programs are now intentionally addressing educational reform strategies in their training for future teachers. Although this training holds promise for ensuring that teachers have the skills to provide effective literacy instruction (e.g., Language Essentials for Teachers of Reading and Spelling) and behavior supports (e.g., Multiple Tiered Systems of Support), little attention has been given to the specific knowledge and skills needed by future educators to utilize technology-enabled instruction as a core aspect of their pedagogical practices to support student learning.

- Provide opportunities for both pre-service and in-service teachers to learn how to analyze and use data provided by math learning software programs to inform teaching and learning. The current study suggests that student learning outcomes are better when teachers use data from math learning software programs to identify areas for improvement in their own content knowledge and teaching skills and to reflect on and discuss learning with individual students. However, teachers rarely reported using data for these purposes. These findings are consistent with evidence that, although learning analytics data has the potential to improve both instruction and learning, it is not currently reaching its potential (Van Schoors, Elen, Raes, Vanbecelaere, & Depaepe, 2023). More work is needed to determine whether the data generated by the various math learning software programs being used by Utah's teachers is generating, in real-time, the types of data that teachers need to gauge the success of their instructional practices and to provide effective support to individual students. Too often teachers "might receive information about the total number of minutes that a student participated in an adaptive learning system without accompanying information about whether the student was participating in active learning or whether the student improved in the percentage of questions answered correctly" (Huebner & Burstein, 2023). Absent well-designed learning analytics data, professional learning focused on using data from math software is bound to fail.

Future Research to Support Technology-Enabled Instruction

The findings from this study suggest three key areas of future research.

- First, more work is needed to understand how frequently teachers are being asked to adopt new math learning software programs, the factors that contribute to more vs. less frequent changes, and the implications of more vs. less frequent changes on teachers' perceptions of the value of software, families' perceptions of the value of software, and student outcomes in different contexts (e.g., economically advantaged vs. economically disadvantaged schools).
- Second, more work is needed to evaluate the effectiveness of professional learning opportunities, including those in teacher preparation programs, to increase the uptake of the promising practices identified in the current study for creating strong, technology-enabled learning environments.
- Third, more work is needed to understand the types of learning analytics data most needed and desired by teachers (see Van Schoors et al., 2023). For example, future studies can address how useful teachers find the types of learning analytics data currently available and teachers' ability to interpret

and make use of the available data, including in real-time, to support their professional growth, their application of knowledge and skills to improve instruction, and student learning.

Future research in these areas should be used to improve the efficacy of technology-enabled instruction for student learning. It can also be used to improve the quality and effectiveness of the products designed for this purpose.

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Promising Practices

for Math Learning Software Implementation

1

Select evidence-based math learning software to support teaching and learning

LEAs have access to a range of math learning software programs. Educational leaders and practitioners should select programs with strong evidence of effectiveness in similar contexts.

2

Use math software to support individual instruction with students

Teachers reported that students used math software most often for independent work, but software may be especially likely to lead to achievement gains when it is used to support teachers or tutors as they work with individual students.

3

Set mastery goals rather than time goals for students' use of math software

Although teachers were more likely to report setting time goals for their students' use of math learning software, only mastery goal-setting was associated with achievement gains.

4

Be attentive to data from math software about student performance on specific skills

Although teachers were more likely to report viewing data about the amount of time students were using software, only viewing data about student performance on specific skills was associated with achievement gains.

5

Use math software data to identify areas for strengthening teachers' content knowledge or teaching skills

Teachers reported rarely using data from math learning software to inform their instruction. However, using data to identify areas to strengthen educators' content knowledge or teaching skills was associated with achievement gains.

6

Use math software data to reflect on and discuss learning with students

Using data to reflect on and discuss learning with students was also associated with achievement gains.

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