THE UNIVERSITY OF UTAH
UTAH EDUCATION POLICY CENTER

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TEACHING MATHEMATICS WITH TECHNOLOGY IN UTAH

An Evaluation of Teacher Knowledge, Practices, and Outcomes with Using Mathematics Personalized Learning Software

PREPARED BY THE UTAH EDUCATION POLICY CENTER ON BEHALF OF THE UTAH STEM ACTION CENTER

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PART ONE:

INTRODUCTION

This section sets the context for the evaluation by reviewing literature on mathematics education in the United States. The review addresses topics including, but not limited to, the personal and societal benefits of rigorous K-12 mathematics education; the performance of U.S. K-12 students in mathematics; the rising use of digital mathematics software in U.S. K-12 classrooms; and the role of teacher quality in effective integration of digital technologies in instruction. In Part One, the report also provides an overview of the K-12 Math Personalized Learning Software Grant Program, the evaluation's methods, and the report's organization.

Setting the Context

The Private and Social Benefits of High-Quality K-12 Mathematics Education

Receiving a rigorous mathematics education at the K-12 level serves both personal and societal interests. At the personal level, obtaining a high-quality pre-college education in mathematics, and STEM (Science, Technology, Engineering, and Mathematics) more generally, has been found to be strongly correlated with scoring higher on standardized college entrance examinations, enrolling in a four-year university, pursuing a major in a STEM field, and graduating with a bachelor's degree (Darling, 2010; McCormick, Rorrer, Onuma, Moore, & Pecsok, 2020; Robinson, 2003; Walston & McCarroll, 2010; Zelkowski, 2008). Moreover, STEM degree recipients in the United States have access to occupations that provide significantly higher earnings and are much less susceptible to economic downturns (Berhane, Onuma, & Secules, 2017).

At the societal level, the benefits of a populace that is mathematically competent is equally notable. For centuries, economic growth in the United States, as with other highly technological nations, has been driven in large part by innovations often spearheaded by individuals with backgrounds in mathematics or engineering (May & Chubin, 2003; U.S. Congress Joint Economic Committee, 2012). Such scientific and technological advances are also chiefly responsible for the United States' position as global leader in the STEM arena. However, as researchers, policymakers, and industry alike maintain, the nation must bolster its production of STEM degree recipients if it is to remain competitive in today's fierce global economy (National Science Foundation, 2014; President's Council of Advisors on Science and Technology, 2012).

The Underperformance of U.S. K-12 Students in Mathematics

Sustaining the nation's success in STEM demands that important attention is given to its K-12 and higher education systems. And as noted, the nation's STEM pipeline is especially "leaky" at the K-12 level (Desilver, 2017; Hossain & Robinson, 2012; Ladson-Billings, 1997; McCormick & Lucas, 2011). Over the past decade, scrutinization of the U.S. K-12 system by the local and international communities has risen due to mounting evidence about the inadequate preparation that U.S. school-age students receive in mathematics and their paltry performance on international assessments in comparison to their Asian and Finnish counterparts (Desilver, 2017; McCormick & Lucas, 2011). As researchers have found, U.S. K-12 students, on a general level, do not receive sufficient exposure to mathematics to meet even college readiness benchmarks (ACT, 2014). Moreover, this issue is especially pronounced among students of color whom, as evidence reflects, are more likely to be clustered in low-ability mathematics classes, discouraged from enrolling into advanced mathematics courses by teachers, and represented in school districts with limited availability of Advanced Placement (AP) and International Baccalaureate (IB) mathematics course options (Berhane at al., 2017; Berry III, Ellis, & Hughes, 2014; Harper, 2010; Ladson-Billings, 1997). Data on the mathematics performance of U.S. K-12 students on international assessments is equally troubling. Desilver (2017) notes that on the most recent Programme for International Student Assessment (PISA), an international examination that measures reading ability and math and science literacy among students who are roughly 15 years of age, the United States ranked 38th out of the 71 countries that participated; moreover, when

compared to the 35 member countries of the Organization for Economic Cooperation (OECD), the United States places at an unremarkable 30th out of the 35 countries.

The Role of Teacher Quality in the Performance of U.S. K-12 Students in Mathematics

Fortunately, the large-scale underperformance of U.S. students in mathematics has little, if any, to do with their ability. Unfortunately, it is due in significant part to a more systemic issue, including that the subject matter knowledge and pedagogical practices of mathematics K-12 educators is inadequate. As researchers have found, mathematics teachers in U.S. schools often receive inadequate training in mathematics themselves, leaving them largely unable to provide the demanding curriculum necessary for students' deep understanding of mathematics and competitive performance on a global level (Hossain & Robinson, 2012; Jensen, Roberts-Hall, Magee, & Ginnivan, 2016; Swars, Smith, Smith, Carothers, & Myers, 2016). Describing this issue in 2008, the National Mathematics Advisory Panel noted that, "it is self-evident that teachers cannot teach what they do not know" (p. xxi). In other words, it is difficult, if not impossible, for teachers to provide substantive instruction in a subject area in which they themselves do not have strong grounding or foundational knowledge. Weak training in mathematics is particularly prevalent among elementary teachers whom are typically prepared as generalists—that is, to teach all subjects—and lack confidence in their abilities to teach mathematics or to even perceive themselves as mathematics teachers, even though they are (Reys & Fennell, 2003; Jensen et al., 2016; Stewart, 2009). Moreover, the poor training of U.S. K-12 mathematics teachers often results in unimaginative and ineffective pedagogical practices that emphasize activities with low cognitive demands such as repetition, drill, and formulas (Berry III et al., 2014).

Benefits of Digital Mathematics Software for Students' Achievement in Mathematics

In an effort to enhance mathematics learning in K-12 classrooms, mathematics education reform in the United States ushered in the use of information and communications (ICT) technology in instruction (Li & Ma, 2010). To make the case for its use, the National Council of Teachers of Mathematics (NCTM) in 2000 asserted that "technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (NCTM as cited in Li & Ma, 2010, p. 216). In recent years, researches have pointed to the increased use of technology in mathematics instruction and the significant investments being made by school districts around the country to procure software for teaching and learning (Cheung & Slavin, 2013; Li & Ma, 2010). Several research studies, since 2000, have also produced findings that confirm the sentiments of the NCTM (Kiger, Herro, & Prunty, 2012; Cheung & Slavin, 2013; Li & Ma, 2010). In 2010, Li and Ma conducted a meta-analysis of the effects of computer technology on K-12 students' mathematics learning and found that computer technology has a moderate but significantly positive effect on mathematics achievement. In 2012, Kiger, Herro, and Prunty explored the effects of a mobile learning intervention on third grade mathematics achievement and found that third grade students who utilized the mobile learning intervention scored significantly higher than comparison students on a post-intervention multiplication test. And in 2013, Cheung and Slavin sought out to understand the effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms and found that educational technology produced moderate positive effects on students' mathematics achievement in comparison to traditional methods.

The Role of Teacher Knowledge in Effective Integration of Digital Mathematics Software

While a number of research studies have, in fact, observed positive effects for educational technology on mathematics learning and achievement, researchers caution that educational technology does not singly, or by itself, produce these effects (Cheung & Slavin, 2013; Li & Ma, 2010). Rather, they contend that educational technology is more often effective when used by teachers with adequate knowledge about the technology and ways to implement it to bring about educational goals (DeCoito & Richardson, 2018; Rahman, Krishnan, & Kapila, 2017). Indeed, several studies have utilized the Technological Pedagogical Content Knowledge (TPACK) framework, posited by Mishra and Koehler in 2006, to explore the role that knowledge plays in effective technology integration. And many have found that teachers with TPACK—the most robust form of the seven forms of knowledge identified by Mishra and Koehler (2006)—are better able to employ technology to create alternative methods of representing disciplinary content to facilitate students' comprehension of challenging course material (Rahman et al., 2017). Despite this finding, researchers have consistently noted a strong and troubling disconnect between mathematics teachers' use of technology and TPACK (DeCoito & Richardson, 2018; Gonzalez & González-Ruiz, 2017; Urbina & Polly, 2017). Put another way, researchers more often note that mathematics' teachers use of technology neither reflects a possession of TPACK nor the educational potential of the technology. As DeCoito and Richardson (2018) described it, mathematics teachers are confident about their knowledge of content, pedagogy, and technology; however, their use or intended use of technology suggests that they are poorly informed about how to effectively utilize technology to teach different course content (an indicator of technology content knowledge or TCK). Relatedly, they are largely unaware about how the culminating form of knowledge, TPACK, can be used to fully realize the potential of the technology. Expressing a similar sentiment, Urbina and Polly (2017) opined that despite teaching in one-to-one environments (i.e., classrooms where each student was provided their own technology), elementary classroom instruction rarely employed technology; moreover, when it did, students were often tasked with technology-based activities that required low-level mathematics computations.

Merits of the Current Evaluation

The current report extends the bodies of literature reviewed above in its evaluation of the knowledge, practices, and outcomes of mathematics teachers in Utah who utilize mathematics personalized learning software in their instruction. The next section of the introduction provides a broad overview of the *K-12 Math Personalized Learning Software Grant Program* that made possible Utah teachers' procurement of mathematics education technology.

Overview of the K-12 Math Personalized Learning Software Grant Program

In 2013, House Bill 139 (H.B. 139)[1], passed in the Utah State Legislature, called for the creation of a Science, Technology, Engineering, and Mathematics (STEM) Action Center and a STEM Education Related Instructional Technology Program (commonly referred to as the *K-12 Math Personalized Learning Software Grant Program*). As stipulated in the bill text, the STEM Action

[1] https://le.utah.gov/~2013/bills/static/HB0139.html

Center Board is to fulfill the following responsibilities in relation to the K-12 Math Personalized Learning Software Grant Program: 1) vet and identify providers of education related instructional technology; 2) select school districts and charter schools to which the technology will be distributed; and 3) provide related professional development to school districts and charter schools that receive the technology. In calling for the establishment of the STEM Action Center and creation of the K-12 Math Personalized Learning Software Grant Program, the overarching goal of H.B. 139 is to improve student outcomes in mathematics and prepare secondary students for college mathematics courses.

Program Implementation

In administering the K-12 Math Personalized Learning Software Grant Program, the STEM Action Center takes guidance from H.B. 139. Guidance provided by H.B. 139 includes criteria for the STEM Action Center to consider in choosing vendors of educational related instructional technology, selecting school districts and charter schools for participation in the grant program, and providing professional development to teachers who receive the technology. In keeping with stipulations in H.B. 139, the STEM Action Center chooses vendors whose digital mathematics software provides individualized instructional support to students using the software, adapts to the needs and progress of each user, provides frequent, quick, and informal assessments, and comes equipped with a tool for monitoring the progress of students and providing feedback to students and teachers.

School districts and charter schools selected to participate in the grant program are also chosen through a competitive process as required by H.B. 139. Finally, with regard to professional development, the STEM Action Center, as mandated by H.B. 139, supports educators in making instructional materials more dynamic and engaging, creating targeted instruction for students who are not enthusiastic about STEM, designing engaging engineering courses, and introducing other research-based methods that support student achievement in STEM.

Purpose of the Evaluation

Given teachers' use of mathematics personalized learning software and exposure to relevant professional development, the current evaluation seeks to assess their knowledge, practices, and outcomes from using mathematics personalized learning software.

Methods

Evaluation Questions

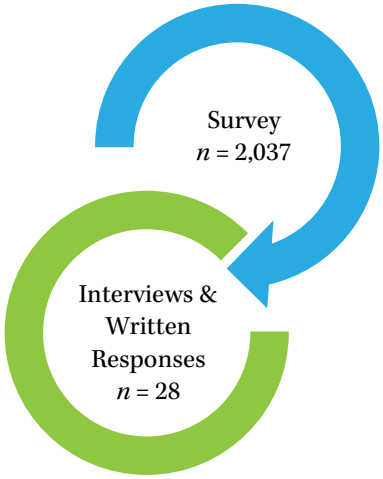
The purpose of the evaluation is addressed through the following questions:

1. What are the demographics of teachers who use mathematics personalized learning software in their classrooms?
2. What forms of knowledge do teachers who use mathematics personalized learning software possess?
3. What are the practices of teachers in classrooms supported by mathematics personalized learning software?
4. How does teaching with mathematics personalized learning software affect teacher outcomes?

Data Sources

Data for this evaluation was collected using instruments designed by the Utah Education Policy Center (UEPC). These instruments included a survey and an interview protocol. The survey served as the primary means of data collection and garnered a total of 2,037 responses. The interview protocol was used in conducting individual interviews, which for this initial study yielded three participants. Additionally, the interview protocol was transformed into an on-line submission form for use in gathering written responses from teachers (n = 25) who were interested in participating in interviews but were unable to do so because of major alterations to their schedules and teaching arrangements brought on by the novel coronavirus, or COVID-19, pandemic.

Figure 1. Data Sources



Survey and Interview Protocol Design

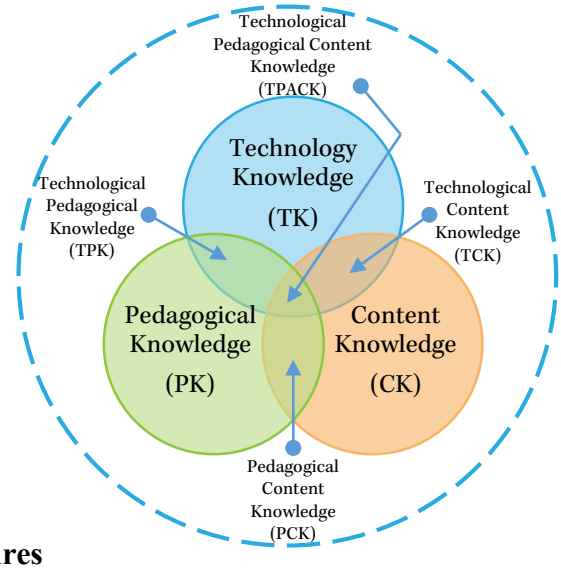
The survey used in this evaluation included items on teacher demographics, knowledge, practices, and outcomes. The interview protocol, however, focused primarily on teacher practices.

Items in the survey pertaining to teacher knowledge were informed by the Technological Pedagogical Content Knowledge (TPACK) framework developed by Mishra and Koehler (2006). As the scholars note, effective integration of technology in the classroom hinges on teachers' possession of knowledge that is complex, multi-faceted, and nuanced. Whereas prior theories, such as that espoused by Shulman (1986), emphasized the importance of content knowledge, pedagogical knowledge, and pedagogical content knowledge (created by the interaction of content and pedagogy), Mishra and Koehler maintain that these forms of knowledge are not sufficient for effective teaching in the current era where classrooms are more often supported by technology.

They argue that good teaching requires knowledge of content (C), pedagogy (P), and technology (T). More importantly, they note that these three forms of knowledge, when used in tandem, activate other forms of knowledge that are also integral to effective teaching. These additional knowledge forms include Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological

Pedagogical Content Knowledge (TPACK). Survey items related to teacher knowledge therefore draw on tenets of the TPACK framework and aim to shed light on the breadth of knowledge possessed by mathematics teachers in technology-supported classrooms.

Figure 2. TPACK Framework



Data Collection Procedures

The survey developed for this evaluation was launched in early March 2020 and stayed open for four weeks. On the day of the survey launch, the UEPC shared the survey link with the STEM Action Center. In turn, the STEM Action Center contacted administrators at school districts and charter schools participating in the grant program and asked that they disseminate the link to their teachers. Over the course of the survey participation period, the UEPC maintained contact with the STEM Action Center and provided them with updates about participation.

The final question in the survey was used to recruit participants for the interview phase of the evaluation. Survey participants who were interested in participating in interviews were asked to provide their name and an email address at which they could be reached. While the initial plan, as discussed in the final survey question, was to conduct focus group interviews, impediments caused by the COVID-19 pandemic necessitated a switch to individual interviews and creating an alternate format (i.e., a form with the interview protocol) through which interested teachers could share written responses to interview questions.

Data Analysis

Survey responses provide data for answering all four evaluation questions. Interviews and written responses to the interview protocol, on the other hand, only provide insight into the third evaluation question that pertains to teacher practices in classrooms supported by mathematics personalized learning software. In analyzing close-ended responses in the survey, we used descriptive statistics (e.g., frequencies, averages, and percentages). Additionally, to represent data from close-ended questions formatted as Likert scale items, bar graphs were utilized that organize data from positive to negative (e.g., strongly agree to strongly disagree). Open-ended survey data, interview data, and written responses to the interview protocol were analyzed using open or inductive coding, which is a process of aggregating responses using themes that emerge directly from the data (Merriam, 2009). The inductive coding process for open-ended responses

was undertaken by two researchers who each read the responses in their entirety and conferred with one another about the themes they gleaned from the data. This process of "investigator triangulation" was done to ensure the rigor and validity of the evaluation's qualitative analysis (Merriam, 2009, p. 216).

Table 1. Data Sources for Evaluation Questions

Evaluation Questions	Data Sources	
	Survey	Interviews & Written Responses
Q1: What are the demographics of teachers who use mathematics personalized learning software?	✓	
Q2: What forms of knowledge do teachers who use mathematics personalized learning software possess?	✓	
Q3: What are the practices of teachers in classrooms supported by mathematics personalized learning software?	✓	✓
Q4: How does teaching with mathematics personalized learning software affect teacher outcomes?	✓	

Report Organization

This introduction constitutes the first of seven sections of this report. The second section of the report, *Terminology and Definitions,* provides definitions for terms used in the report to describe the forms of knowledge that teachers possess and their instructional practices. *Demographics,* the report's third section, provides key demographic data about teachers who participated in the evaluation. The fourth section of the report, *Teacher Knowledge,* covers the forms of knowledge possessed by teachers who utilize mathematics personalized learning software in their instruction. *Teacher Practices,* the report's fifth section, examines the practices of teachers who incorporate digital mathematics technologies in their instruction. The sixth section of the report, *Teacher Outcomes,* explores teachers' outcomes from incorporating mathematics personalized learning software in their instruction. Finally, the seventh section of the report, *Conclusions and Considerations,* provides a summary of the report's findings as well as considerations for the K-12 Math Personalized Learning Software Grant Program.

PART TWO:

TERMINOLOGY & DEFINITIONS

This section provides definitions for terms used in the report to describe the forms of knowledge that teachers possess. It also reviews terms used in the report to refer to teachers' instructional practices. The forms of knowledge that are of interest in the current report include content knowledge, pedagogical knowledge, pedagogical content knowledge, technology knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge. The instructional practices covered in this report include pre-assessments, formative assessments, summative assessments, differentiation, remediation, enrichment, homework, and supplementary classroom practice.

Forms of Knowledge

Content Knowledge – Knowledge about the actual subject matter that is to be learned or taught (Mishra & Koehler, 2006).

Pedagogical Knowledge – Knowledge of the process, practices, and methods of teaching and learning (Mishra & Koehler, 2006).

Pedagogical Content Knowledge – Knowledge of the process, practices, and methods that are most appropriate for teaching a specific content (Mishra & Koehler, 2006).

Technology Knowledge – Knowledge of mainstream technologies, such as chalkboards, and digital technologies, such as educational software and the internet (Mishra & Koehler, 2006).

Technological Content Knowledge – Knowledge of the ways in which technology can be employed to teach a specific content and the manner in which a subject matter can be changed by integrating technology (Mishra & Koehler, 2006).

Technological Pedagogical Knowledge – Knowledge of the existence, components, and utility of various technologies and how teaching can be modified by integrating particular technologies (Mishra & Koehler, 2006).

Technological Pedagogical Content Knowledge – Regarded as the basis of good teaching, technological pedagogical content knowledge requires thoughtful integration and utilization of the three key forms of knowledge: content knowledge, pedagogical knowledge, and technology knowledge ((Mishra & Koehler, 2006).

General Instructional Practices

Pre-Assessments – Evaluations administered prior to the start of a lesson, unit, or course to assess students' prior knowledge and establish a baseline against which to measure learning progress in relation to the lesson, unit, or course to be taught (Brownstein et al., 2009).

Formative Assessments – Evaluations administered during the learning process to assess students' learning progress and, if needed, modify teaching and learning to improve student achievement (Schoenfeld, 2015).

Summative Assessments – Evaluations administered at the conclusion of a lesson, unit, or course to assess what students learned or did not learn. Examples of summative assignments include end-of-unit tests and state assessments (Schoenfeld, 2015).

Differentiation – A practice of putting comparable emphasis on individual students and course content and adapting teaching and learning to accommodate each individual student's prior knowledge, interests, abilities, and learning style. (Tomlinson & Imbeau, 2010).

Remediation – The practice of giving additional time, guidance, and instruction to a student in order to ensure that they achieve pre-set learning goals (Grant, Fazarro, & Steinke, 2014).

Enrichment – The practice of assigning additional tasks to students who have met learning goals in order to further their

knowledge on the subject matter (Grant et al., 2014).

Supplementary Classroom Practice – The practice of assigning additional problems to students to help assess and reinforce their knowledge of concepts (Parsons & González, 2018).

Homework – Tasks assigned by teachers that are intended to be completed by students outside of school hours and are to help reinforce newly acquired skills and knowledge and facilitate the acquisitions of new skills through independent study (Cooper, Robinson, & Patall, 2006).

PART THREE:

DEMOGRAPHICS

This section examines the demographics of the 2,037 teachers who participated in the survey that informed this report. As teachers who participated in interviews, or submitted written responses to the interview protocol, were also survey respondents, their demographics are reflected in the data provided below.

Key Findings on Participant Demographics

Teachers Who Use Mathematics Personalized Learning Software in their Classrooms Are Affiliated with a Variety of Local Education Agencies

Teachers who teach mathematics with technology were asked to identify the local education agencies in which they teach. As Table 2 illustrates, these teachers belong to a variety of local education agencies including public school districts and charter schools. Precisely, 1,763 teachers indicated that they provide mathematics instruction in public school districts and 274 indicated that they teach mathematics at charter schools. Of the public school districts listed in Table 2, however, Davis District (n = 517), Granite District (n = 392), Canyons District (n = 167), Salt Lake District (n = 94), and Alpine District (n = 80) account for the highest numbers of teachers who teach mathematics with technology.

Teachers Who Use Mathematics Personalized Learning Software Teach Varied Grade Levels, Although They Primarily Serve the 3rd, 4th, and 5th Grades

Teachers were asked in the survey to identify the grade levels that they teach (Figure 3). As Figure 3 depicts, teachers who use mathematics personalized learning software in their instruction teach a variety of grade levels, spanning kindergarten to grade 12. Additionally, many teach more than one grade level as indicated by the percentages in Figure 3 that sum up to more than 100%. As it concerns the grade levels in which these teachers most frequently teach, a notable proportion of them report teaching grades 3 (22%), 4 (21%), 5 (20%). Also, teachers were least likely to indicate that they teach grades 9 (5%), 10 (5%), 11 (4%), and 12 (3%).

Figure 3. Grade Levels Taught by Teachers

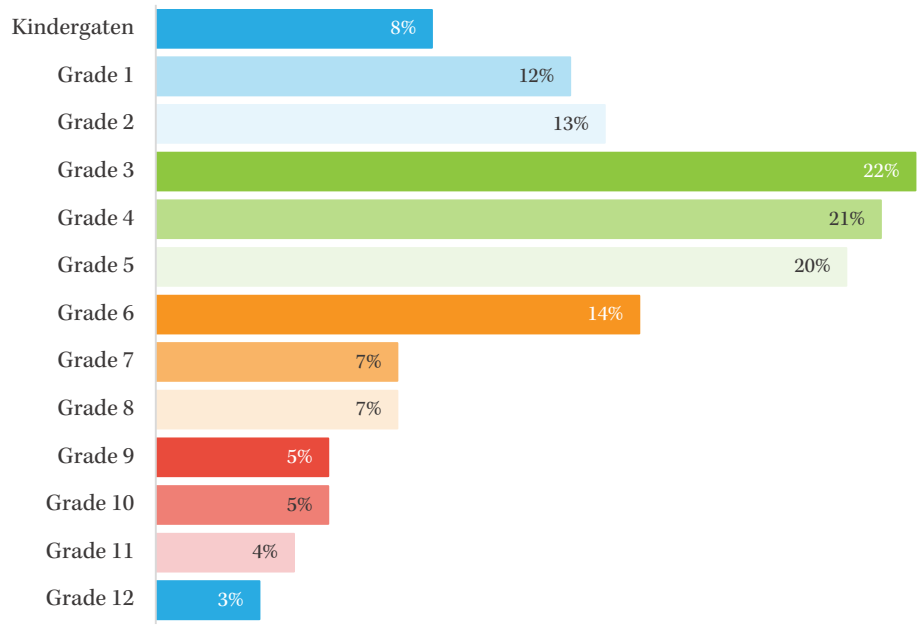


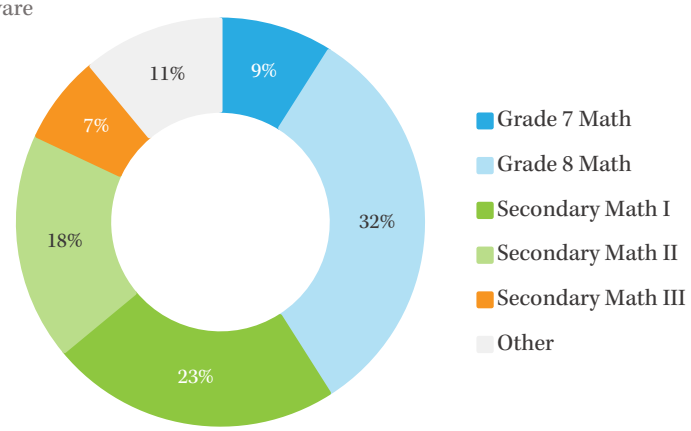
Table 2. Local Education Agencies and Number of Survey Respondents

Local Education Agencies (No. of Survey Respondents)			
Alpine District	(80)	Nebo District	(3)
Beaver District	(1)	North Sanpete District	(7)
Box Elder District	(1)	Ogden City District	(1)
Cache District	(19)	Park City District	(13)
Canyons District	(167)	Piute District	(14)
Carbon District	(3)	Provo District	(6)
Davis District	(517)	Rich District	(8)
Duchesne District	(8)	Salt Lake District	(94)
Emery District	(17)	San Juan District	(35)
Garfield District	(3)	Sevier District	(56)
Grand District	(16)	South Sanpete District	(21)
Granite District	(392)	South Summit District	(15)
Iron District	(9)	Tintic District	(5)
Jordan District	(52)	Toole District	(18)
Juab District	(24)	Wasatch District	(1)
Kane District	(9)	Washington District	(37)
Logan City District	(29)	Wayne District	(2)
Millard District	(14)	Weber District	(54)
Morgan District	(11)	Charter Schools	(274)
Murray District	(1)	Total	(2,037)

Among the Various Middle and High School Mathematics Courses Offered, Teachers Most Frequently Integrate Digital Mathematics Software in Grade 8 Math

Given that teachers often teach more than one grade level—a fact that also holds true for our sample as discussed in the prior finding—teachers were further prompted in the survey to specify the mathematics course in which they most frequently integrate digital mathematics software. To answer this question, teachers were provided with options including *Grade 7 Math*, *Grade 8 Math*, *Secondary Math I*, *Secondary Math II*, *Secondary Math III*, *Pre-Calculus*, *Introductory Calculus*, *AP Calculus*, *AP Statistics*, *College Prep Math*, *Mathematical Decision Making for Life*, *Mathematics of Personal Finance*, *Modern Mathematics*, and *Other*. As Figure 4 shows, teachers more regularly integrate digital mathematics software in *Grade 8 Math* (32%) and two required high school mathematics courses—*Secondary Math I* (23%) and *Secondary Math II* (18%). It is also important to note that among the teachers who indicated that they teach "other" mathematics courses (11%), many noted teaching *Grade 6 Math* (another middle school mathematics course) and *Applied Mathematics* courses (mathematics course options that are usually only available to high school students).

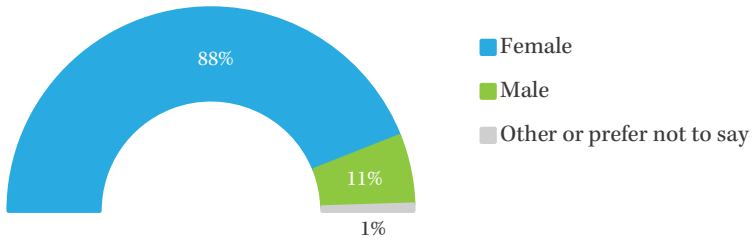
Figure 4. Middle and High School Mathematics Courses in Which Teachers Most Often Integrate Mathematics Personalized Learning Software



The Vast Majority of Teachers Who Teach Mathematics with Technology Are Female

Teachers were also asked in the survey to identify their gender. As Figure 5 illustrates, teachers were most likely to indicate that they were female (88%). Eleven percent of teachers indicated that they were male, and 1% selected the option of "other or prefer not to say."

Figure 5. Gender of Survey Respondents



Most Teachers Who Teach Mathematics with Technology Hold a Degree in Teaching but Not in Mathematics

Teachers who teach mathematics with technology were asked to indicate whether or not they have a degree in teaching (Figure 6). Additionally, they were also asked if they have a degree in mathematics (Figure 7). As Figure 6 suggests, the majority of teachers (86%) who utilize digital technologies in their mathematics instruction have a degree in teaching. At the same time, however, an overwhelming majority of them (94%) do not hold a mathematics degree (Figure 7).

Figure 6. Percent of Teachers Who Hold or Do Not Hold a Degree in Teaching

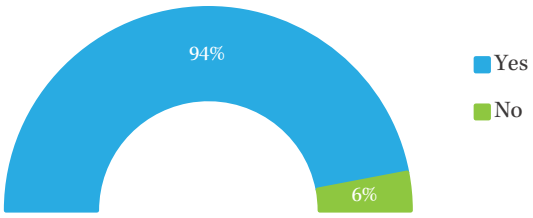
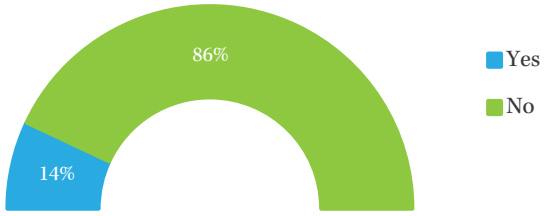


Figure 7. Percent of Teachers Who Hold or Do Not Hold a Degree in Mathematics



Many Teachers Who Use Mathematics Personalized Learning Software Have or Are Working Towards Endorsements

Teachers were asked to identify the endorsements, if any, they had or were working towards from the following options: business marketing/information technology; educational technology; gifted and talented; instructional coaching; mathematics; science, technology, engineering, and mathematics (STEM); special education; and other. Figures 8 and 9 report data on teachers who indicated that they had earned or were working towards endorsements. As Figure 8 illustrates, the highest number of teachers (n = 404) indicated that they were working towards "other" endorsements not included among the options. When prompted to specify what these "other" endorsements were, many noted seeking, or having already earned, endorsements in English as a second language (ESL), English language learners (ELL), early childhood education, and dual immersion. Besides "other" endorsements, an important fraction of teachers noted having or working towards mathematics (n = 364), educational technology (n = 220), and special education (n = 175) endorsements. Equally importantly, as Figure 9 indicates, teachers who selected special education (91%), other (78%), and mathematics (76%) endorsements were more likely than other teachers to have completed the process required to earn their certifications.

Figure 8. Number of Teachers Pursuing Each Type of Endorsement

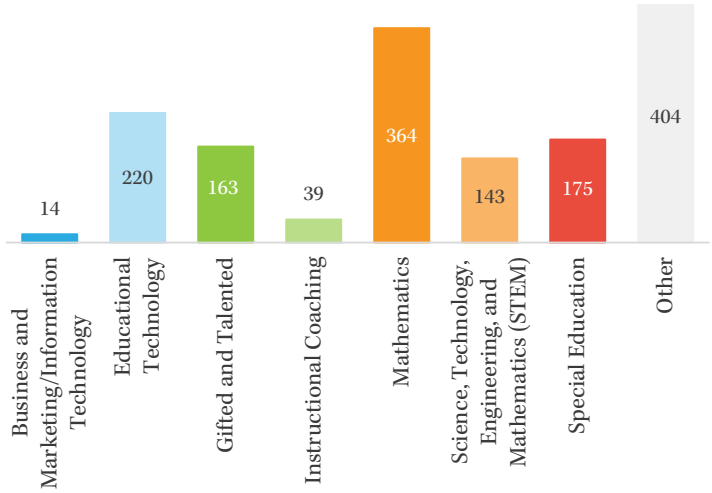
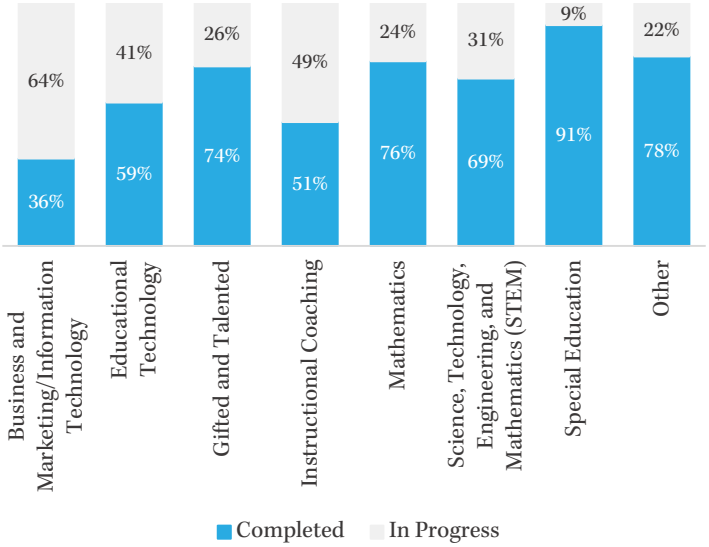


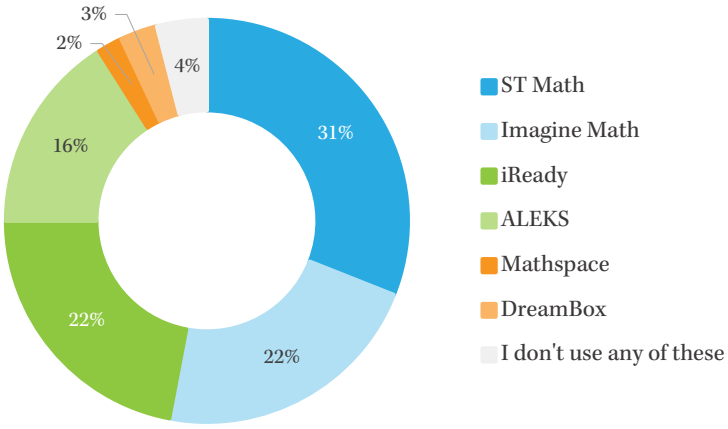
Figure 9. Percent of Teachers Who Have Completed or Are in Progress with Earning Endorsements



The Type of Mathematics Personalized Learning Software Utilized by Teachers Vary

Teachers were provided with a pre-defined list of digital mathematics software supported by the STEM Action Center—ALEKS, DreamBox, Imagine Math, iReady, and ST Math—and were asked to identify which of the software they most frequently use. They were also permitted to indicate that "I don't use any of these" in the case that their digital mathematics software of choice was not provided in the list. As Figure 10 suggests, the digital mathematics software most frequently used by teachers include ST Math (31%), Imagine Math (22%), and iReady (22%), while the least used is Mathspace (2%).

Figure 10. Mathematics Personalized Learning Software Used by Teachers



PART FOUR:

TEACHER KNOWLEDGE

This section explores the forms of knowledge possessed by teachers who use integrate personalized learning software in their mathematics instruction. The requisite forms of teacher knowledge for technology-supported instruction include content knowledge, pedagogical knowledge, pedagogical content knowledge, technology knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge. Definitions for these knowledge varieties are provided in the *Terminology and Definitions* section of this report (i.e., Part Two).

Key Findings on Teacher Knowledge

A Majority of Teachers Strongly Agree or Agree That They Possess the Seven Forms of Teacher Knowledge Necessary for Effective Teaching of Mathematics with Technology

Teachers who use mathematics personalized learning software in their instruction were asked to specify the extent to which they agree that they possess indicators of the various forms of teacher knowledge useful for teaching in such classrooms. As Figures 11-17 illustrate, teachers who integrate technology in their mathematics instruction are generally very confident of their knowledge of content (Figure 11), pedagogy (Figure 12), and technology (Figure 13) as well as their ability to simultaneously utilize two or more of these keys forms of knowledge in their instruction (Figures 14, 15, 16, and 17). Between 82% and 93% of teachers, for example, strongly agreed or agreed that they possess the indicators of content knowledge which include "having sufficient knowledge about mathematics," "knowing various ways and strategies of developing my understanding of mathematics," and "using a mathematical way of thinking" (Figure 11). A somewhat higher percentage of teachers, between 95% and 98% strongly agreed or agreed that they possessed the attributes associated with pedagogical knowledge. Concerning technology knowledge, 61% to 80% of teachers strongly agree or agreed that they possessed its various indicators (Figure 13). For pedagogical content knowledge (Figure 14), technological pedagogical knowledge (Figure 15), technological content knowledge (Figure 16), the percentages of teachers who strongly agreed or agreed to possessing their indicators were 90% to 93%, 78% to 90%, and 77%, respectively. Finally, technological pedagogical content knowledge, the most robust form of teacher knowledge, had 76% of teachers who strongly agreed or agreed that they possessed its sole indicator "I teach lessons that appropriately combine mathematics, technologies, and teaching approaches" (Figure 17). It is important to note here that among teachers who responded affirmatively about possessing the various forms of knowledge, nearly half of them, and in some cases more than half, tended to "agree" as opposed to "strongly agree."

Figure 11. Teachers' Self-Evaluation of Their Content Knowledge

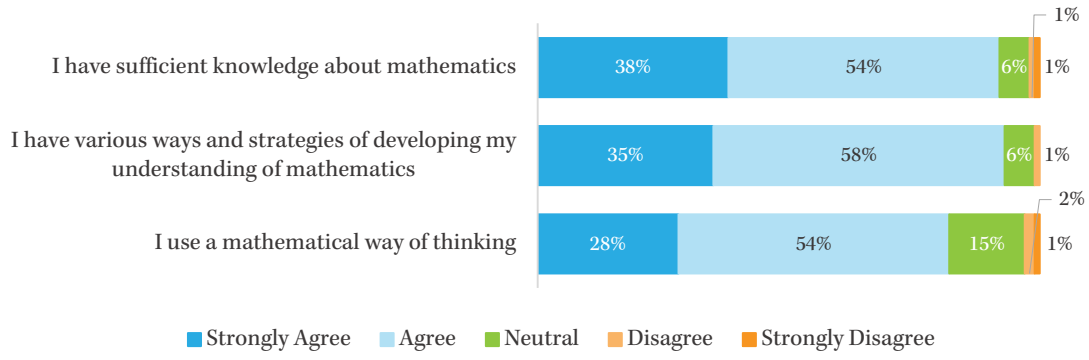


Figure 12. Teachers' Self-Evaluation of Their Pedagogical Knowledge

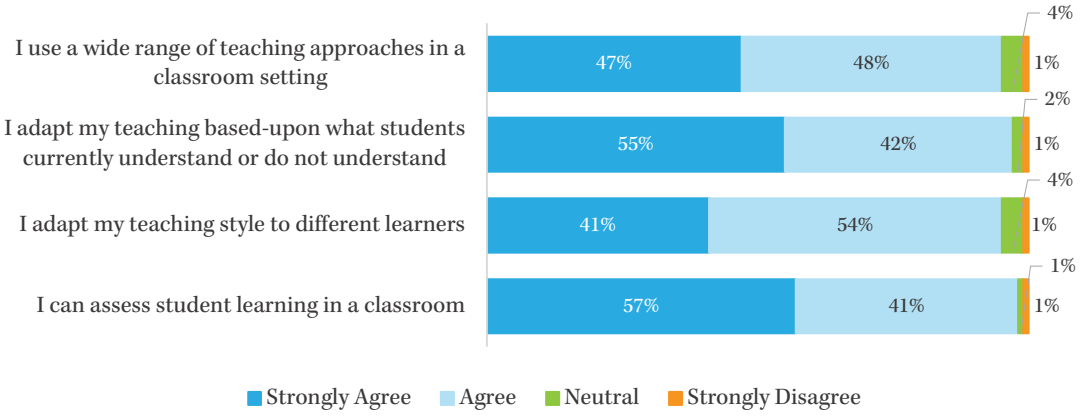


Figure 13. Teachers' Self-Evaluation of Their Technology Knowledge

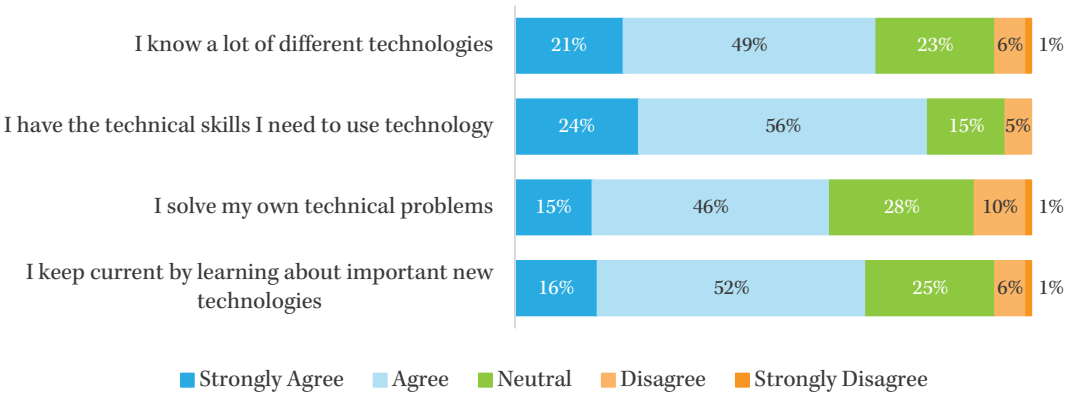


Figure 14. Teachers' Self-Evaluation of Their Pedagogical Content Knowledge

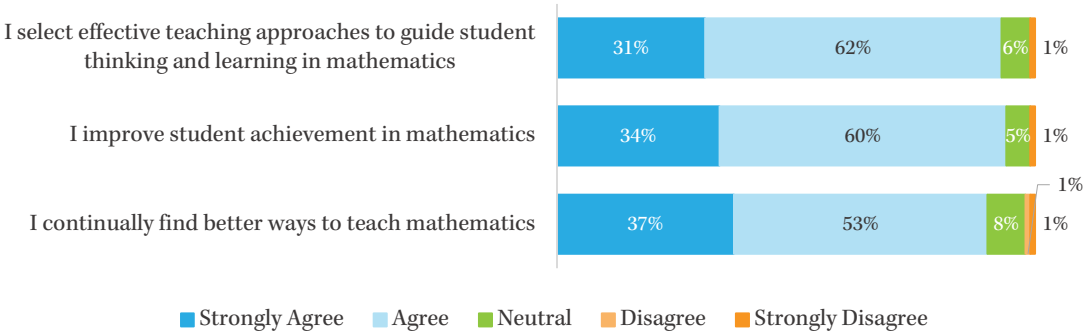


Figure 15. Teachers' Self-Evaluation of Their Technological Pedagogical Knowledge

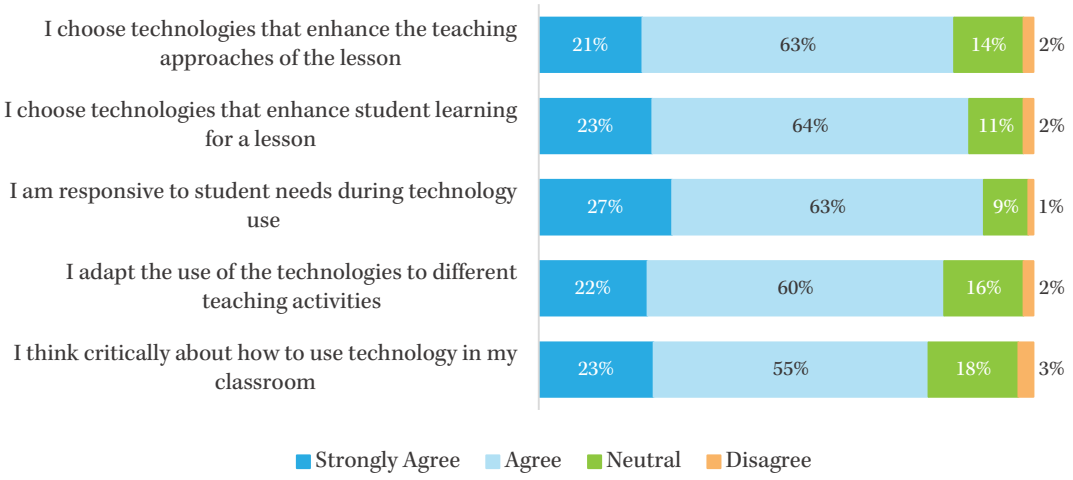


Figure 16. Teachers' Self-Evaluation of Their Technological Content Knowledge

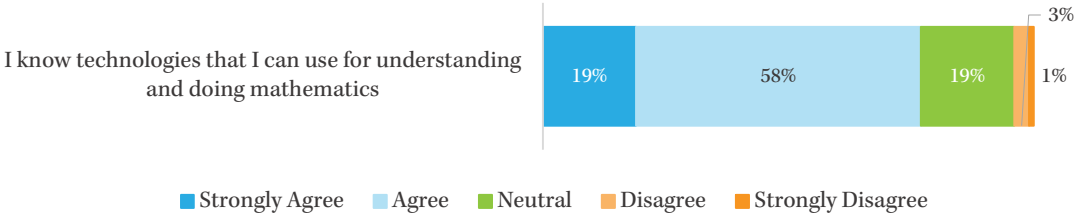
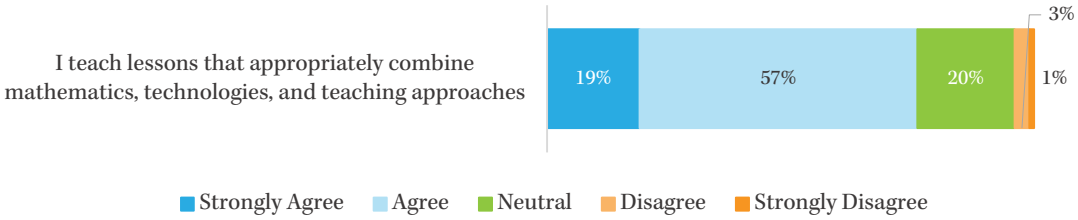


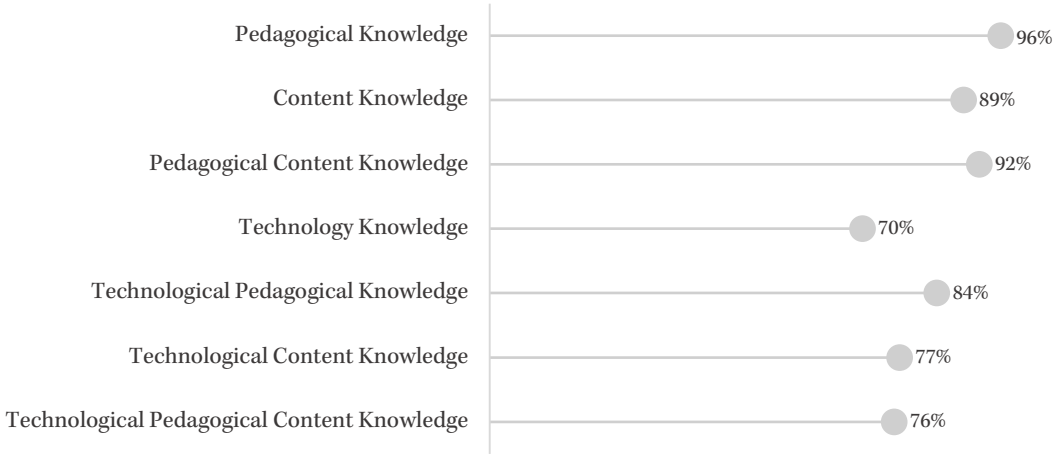
Figure 17. Teachers' Self-Evaluation of Their Technological Pedagogical Content Knowledge



Teachers Who Utilize Mathematics Personalized Learning Software in their Instruction Are Generally More Likely to Possess Pedagogical Knowledge and Pedagogical Content Knowledge

While teachers were relatively very confident about their possession of the various forms of knowledge as indicated in the prior finding, a closer examination of the data reveals that teachers were more likely to strongly agree or agree to having certain forms of knowledge than others. Figure 18 illustrates the average percentage of teachers who strongly agree or agree to possessing each form of teacher knowledge. As the figure reveals, teachers were least likely to indicate that they possess technology knowledge (70%) and technological pedagogical content knowledge (76%). However, they were most likely to strongly agree or agree to having pedagogical knowledge (96%) and pedagogical content knowledge (92%).

Figure 18. Average Percent of Teachers Who Strongly Agree or Agree to Having the Various Forms of Knowledge



PART FIVE:

TEACHER PRACTICES

This section examines the practices of mathematics teachers who incorporate digital technologies in their instruction. Topics discussed include how often teachers integrate technology in their instruction for classroom activities and out-of-classroom assignments (e.g., homework), how effective they perceive mathematics personalized learning software to be for key instructional practices—including pre-assessment, formative assessment, summative assessment, homework, differentiation, remediation, and enrichment—and their perceptions about how technology best supports teaching and learning in their classrooms. Findings concerning how often teachers use technology in their instruction and how effective they rate technology for instructional purposes utilize data from close-ended questions in the survey. On the other hand, findings about how technology best supports teaching and learning in teachers' classrooms are informed by teachers' responses to an open-ended question in the survey, their extended discourses during interviews, and their written responses to the interview protocol. The instructional practices identified above are defined in the *Terminology and Definitions* section of this report (i.e., Part Two).

Key Findings on Teacher Practices

Teachers Who Integrate Technology in Their Mathematics Instruction Use It More Often for Classroom Activities Than for Out-of-Classroom Assignments

Teachers were asked how often they use technology for classroom activities and out-of-classroom assignments. To answer each of the two questions, teachers were provided the following six options to select from: "more often," "2-3 days a week," "about once a week," "2-3 times a month," "once a month or less," and "never." As Figures 19 and 20 suggest, teachers utilize technology more often for in-class instruction than for out-of-classroom assignments. While 84% of teachers indicated using technology "more often," "2-3 days a week," or "about once a week" for classroom activities (Figure 19), only 37% of them indicated using technology that frequently for out-of-classroom assignments (Figure 20). Equally revealing is the percent of teachers who indicated that they "never" use technology. Whereas 6% of teachers indicated "never" using technology for in-class instruction, 43% of teachers indicated that they "never" use technology for out-of-classroom assignments.

Figure 19. Teachers' Frequency of Use of Mathematics Software for Classroom Activities

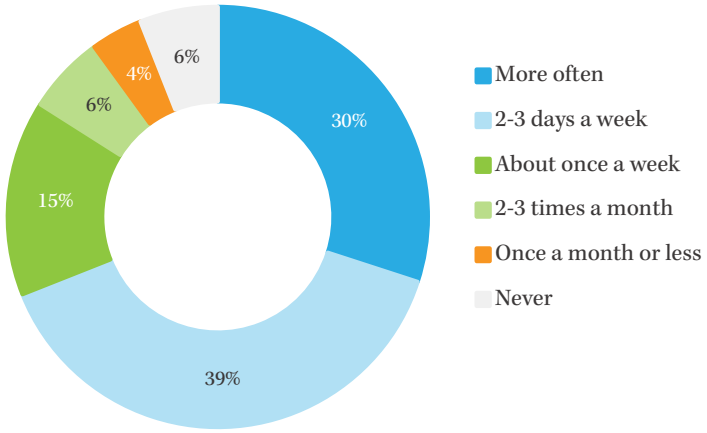
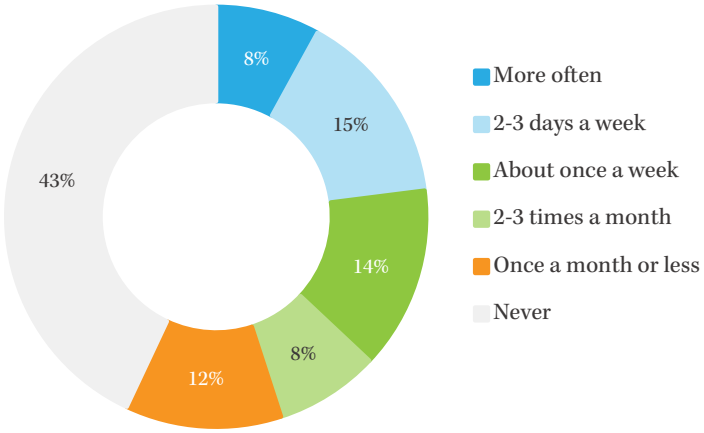


Figure 20. Teachers' Frequency of Use of Mathematics Software for Out-of-Classroom Assignments



Teachers Who Integrate Technology in Their Mathematics Instruction Find It More Effective for Individualized Instructional Activities Than for Group Activities

Teachers who teach mathematics with technology were asked to specify how effective technology is for key instructional practices, including pre-assessment, formative assessment, summative assessment, homework, differentiation, remediation, and enrichment. To rate the effectiveness of technology for the aforementioned purposes, teachers were provided the following options to select from: "extremely effective," "very effective," "moderately effective," "slightly effective," "not at all effective," and "did not use." As Figures 21-27 illustrate, teachers find technology much more effective for instructional practices that center the learning needs of individual students (i.e., differentiation, remediation, enrichment) than those that tend to involve the whole class (i.e., pre-assessment, formative assessment, summative assessment, homework). For example, whereas 35%, 37%, 35%, and 24% of teachers, respectively, indicated that technology is "extremely effective" or "very effective" for pre-assessment (Figure 21), formative assessment (Figure 22), summative assessment (Figure 23), and homework (Figure 24), 61%, 50%, and 67% of teachers, respectively, rated technology as "highly effective" or "very effective" for differentiation (Figure 25), remediation (Figure 26), and enrichment (Figure 27). Teachers were also more likely to indicate that they "did not use" technology for pre-assessment (33%), formative assessment (29%), summative assessment (34%), and homework (44%), than differentiation (10%), remediation (13%), and enrichment (7%).

Figure 21. Teachers' Evaluation of the Effectiveness of Mathematics Software for Pre-Assessment

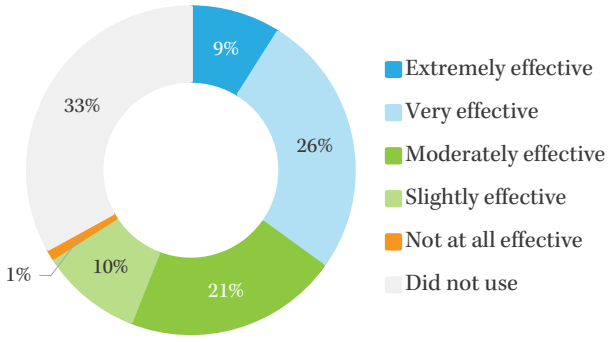


Figure 22. Teachers' Evaluation of the Effectiveness of Mathematics Software for Formative Assessment

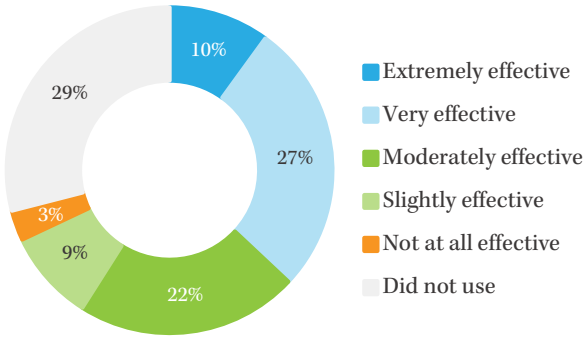


Figure 23. Teachers' Evaluation of the Effectiveness of Mathematics Software for Summative Assessment

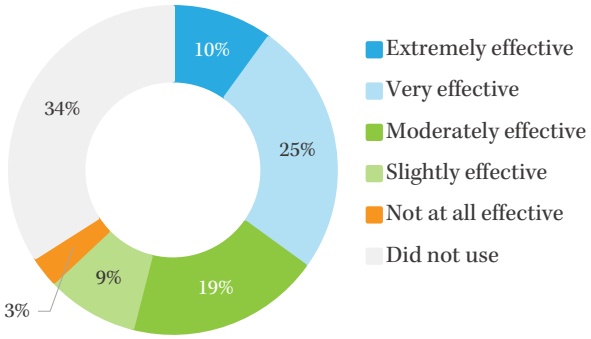


Figure 24. Teachers' Evaluation of the Effectiveness of Mathematics Software for Homework

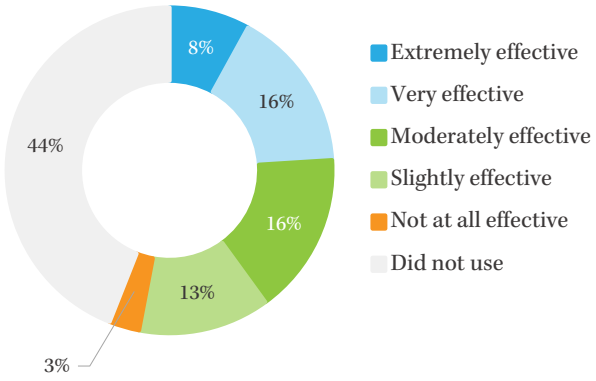


Figure 25. Teachers' Evaluation of the Effectiveness of Mathematics Software for Differentiation

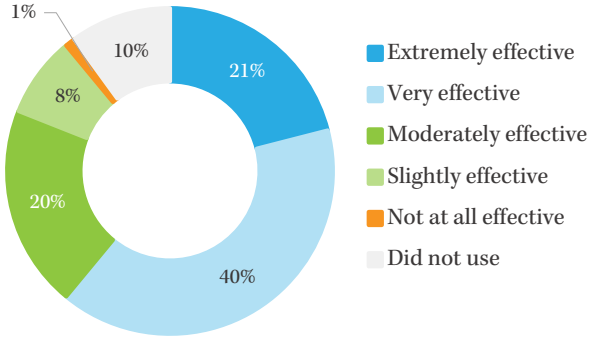


Figure 26. Teachers' Evaluation of the Effectiveness of Mathematics Software for Remediation

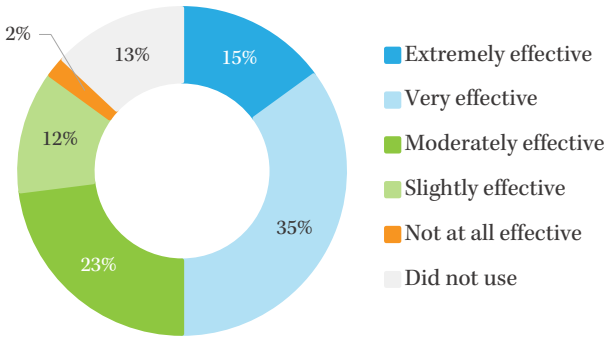
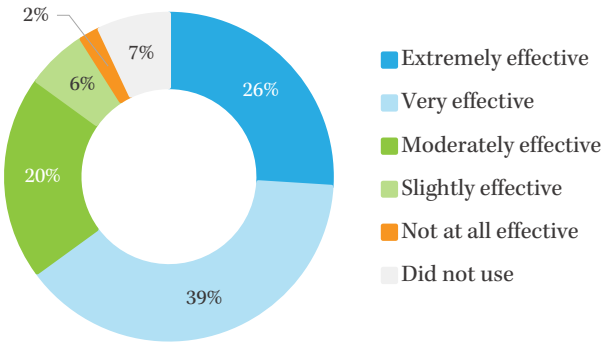


Figure 27. Teachers' Evaluation of the Effectiveness of Mathematics Software for Enrichment



In their Qualitative Responses, Teachers Noted That Technology Best Supported Teaching and Learning in their Classrooms in Various Ways, Although the Most Common Ways Identified Were Differentiation, Remediation, and Enrichment

In the same way that teachers were more likely to note that digital mathematics software was more effective for differentiation, remediation, and enrichment than for pre-assessment, formative assessment, summative assessment, and homework (as illustrated in Figures 21-27), they more frequently discussed in their qualitative responses that digital mathematics software best supported teaching and learning in their classrooms by facilitating the first three practices. To be sure, a few teachers also reported that mathematics personalized learning software was most useful in their instruction for pre-assessment, formative assessment, summative assessment, homework, and even supplemental exercises/practice. In the sub-sections below, we discuss these themes that emerged from the study's qualitative data and provide excerpts from teachers' accounts that best illustrate them.

Differentiation: Individualizing Instruction

Because no two students are alike, as Tomlinson and Imbeau (2005) opine, personalization of teaching and learning is a necessity. Much like Tomlinson and Imbeau (2005), teachers who participated in the study know first-hand the range of skills and abilities that can be present in a single classroom. As one teacher reported, *"I have students who cannot count to 10. I have students who were…proficient in 5th grade math since the first day of school year, and I have students at every level in between. In essence I have about 20 levels."* As another noted, *"each of my students is at a very different level."*

Given the great variation in academic readiness, interests, and needs that teachers often encounter in the classroom, many see the importance of paying careful attention to each student's learning progress and assigning tasks to students that are appropriate for their level of understanding. Describing the value she places on differentiating instruction for her students, one teacher noted, *"It is vital for me that I can look at a domain or area in which a student is struggling, pull up a lesson plan targeting that area, and teach a lesson one-on-one with that student."* In a similar vein, another teacher reported, *"students that work with me in small groups get to work with their own level, and we get to have individualized instruction one on one with where they are at in their learning."*

While differentiation is a practice that many teachers, like those highlighted above, find incredibly useful for fostering students' comprehension of course content and even their confidence, many also acknowledge the time-consuming nature of the practice and credit mathematics personalized learning software for increasing their efficiency at providing individualized instruction to their students. Describing the challenge of differentiation and the importance of digital technologies for this practice, one teacher asserted, *"I don't have time to differentiate for 60 students a day but this program allows them to work at their own pace."* Similar to this teacher, another noted, *"I can differentiate a little easier using technology than if I were just on my own."*

As teachers' accounts further revealed, mathematics personalized learning software did not merely serve to make their differentiation practice easier. Many teachers spoke at length about at how effective these digital technologies were at recognizing the learning needs of students and providing targeted tasks that accommodate their skills and abilities. As one teacher described, *"At the beginning of the year most students were on the same module…As the year progressed and students were at different levels of [software], student learning targets changed."* Also speaking about the level of personalization in instruction provided by digital mathematics software, another teacher said, *"each student was given individual goals through [software] rather than following the whole class target."* Similarly, another teacher noted, *"I like how [software] is geared to the student's level and aids in filling the gaps students may have."*

Indeed, when teachers were asked to provide one word that best describes the role of mathematics personalized learning software in their classroom, a good number of them shared words that capture the ethos of differentiation such as *"personalized," "adaptive,"* and *"individualized",* and *"accessible."*

Remediation: Filling the Holes

Grant, Fazarro, and Steinke (2014) discuss that the goal of mastery learning—that students achieve complete knowledge of material—is increasingly being abandoned in K-12 classrooms across the nation because of the considerable time and effort that it requires. In a typical K-12 classroom, teachers are expected to achieve the goal of mastery learning by teaching a unit or lesson to students, developing an assessment to gauge their understanding of the content, and for learners who did not achieve the mastery necessary, providing remediation. Remediation, with the goal that students should achieve mastery, involves giving additional instruction, followed by an assessment, as many times as is needed until the necessary progress is made. Needless to say, the amount of care and effort exerted in providing remediation or fostering mastery learning appear worthwhile for narrowing or closing achievement gaps in education, and in fact, several researchers have confirmed this to be the case (e.g., Grant et al., 2014; Guskey, 2007). However, the time-consuming nature of the practice has led to its declining popularity in recent years.

Given the arduousness of remediation, it comes as no surprise then that teachers who participated in the study valued mathematics personalized learning software for its ability to serve as a tool for remediation. Alluding to the feeling of relief she experienced because of the effectiveness of digital mathematics software at identifying students in need of remediation, one teacher said, *"I don't need to know where they are lacking in their math understanding because [software] will already do that with an assessment before they start."*

Beyond helping to identify students in need of additional instruction, many teachers shared detailed experiences with using mathematics personalized learning software to support their *"struggling"* students or to *"fill the holes"* in their students' learning. Describing an experience with a struggling student and how she utilized digital mathematics software to provide the needed remediation, one teacher said, *"A student came into my class behind where she should have been. She worked every day on [software] and it brought up concepts she needed help on. I was able to work with her and get her caught up to where she should be, and now she has very few struggles in math."* Similar to this teacher, another reported, *"One of my students was*

struggling with a concept in the University of Utah 6th grade Math book. I was able to choose a lesson on [software] that covered the same concepts. This extra reinforcement and instruction helped the student gain an understanding of the topic."

Not only did teachers describe using mathematics personalized learning software for remediation, many in fact noted that remediation was primarily, if not solely, what they used software for. As one teacher said, *"I have used [software] the most to help students fill in their 'holes'"*. Similarly, another teacher opined, *"I use [software] most successfully in my class to help students who have gaps in their learning."* And another noted pithily, *"I use [software] for remediation."* Many teachers also alluded to using mathematics personalized learning software solely for remediation when they were asked to provide one word that best describes the role of digital technologies in their classroom. In response to this question, some teachers provided the following words: *"support," "aid,"* and *"supplemental."*

Enrichment: Moving Ahead

Much like remediation, enrichment—the practice of assigning advanced tasks to students who have met learning goals or are moving at a faster pace than other learners in the class—requires a considerable amount of time and planning (Grant et al., 2014). To identify students in need of enrichment, teachers must again teach a unit or lesson, create an assessment to measure learning, and for students who have achieved mastery of learning objectives, prepare and provide enrichment exercises (Grant et al., 2014).

Given the time and effort needed to develop unique lessons for students in need of enrichment, teachers in the study also frequently discussed using mathematics personalized learning software for this very purpose. One teacher excitedly shared, *"Each year I have several real top students that thrive because of [software]. They soar through our 5th grade level materials before mid-year. Then they are off to conquer the 6th and even 7th grade levels…[Software] is the best tool I have to keep my highest students showing exceptional growth during their 5th grade year!"* Similar to this teacher, others described using mathematics personalized learning software for their "high achievers," "gifted students," and "fast finishers." According to another teacher, *"[Software] has been very beneficial to those gifted in math. I'm thinking of a particular student who loves it and masters ideas so quickly. He has loved moving ahead of the group and learning new things."* Another teacher also reported, *"For my higher kids, [software] allowed them to move at a faster pace. Once they finished their pathway I was able to add curriculum that would be taught the following year."*

Indeed, the value of mathematics personalized learning software as a tool for enrichment was so extolled by teachers, that many reported using the digital technology mostly, if not only, for this instructional practice. According to one teacher, *"…the most common reason for use of [software] in my classroom is for fast finishers or as an enrichment activity."* Similar to this teacher, another shared, *"I mostly use [software] for fast finishers in my classroom."* As shared by another teacher, *"I only use [software] for early finishers."* And even another said, *"One of the main things I use [software] for is enrichment."*

Pre-Assessment: Understanding Where Students "Place"

Unlike differentiation, remediation, and enrichment, very rarely did teachers discuss using mathematics personalized learning software for pre-assessment. This instructional practice, while not a prevalent purpose for digital mathematics software use among teachers in the study, has been confirmed in research to be extremely critical for effective instructional planning, teaching quality, and the overall learning experience for students (Bautista, 2011; Brownstein et al., 2009).

Among the few teachers who used digital technologies for pre-assessment, two provided the most illustrative descriptions of how their software use facilitates the practice. According to the first teacher, *"[Software] has been used to get a clearer picture of where students place within the different math concepts…The data pulled from [software] helps inform the individual education maps for each of my students in math."* The second teacher shared, *"Students who needed intervention with [counting numbers to 20] were identified with the [software] diagnostic and then provided with teacher led intervention. Growth was assessed with Growth Monitoring in [software]."*

For both of these teachers, and the few others, who use mathematics personalized learning software for pre-assessment, the digital technology facilitates their gathering of diagnostic data on students' prior knowledge, which is then used to inform their lesson planning and to measure students' growth.

Formative Assessment: Using Student Data to Modify Teaching and Learning

Like pre-assessment, formative assessment was infrequently performed by teachers using mathematics personalized learning software. This instructional approach, as research suggests, is equally important as the previously discussed instructional practices. Moreover, it is uniquely important to student learning for the very fact that it involves collecting data about students' understanding midway into the teaching of a lesson or unit—a critical juncture when there are still opportunities to modify teaching and learning to ensure students' mastery of the material (Schoenfeld, 2015).

Among the few teachers who found digital mathematics software useful for formative assessment, some recalled a particular experience from recent memory when they used software for this practice. Recounting her use of digital mathematics software for formative assessment after a lesson on area and perimeter, one teacher said *"I taught multiple lessons on area and perimeter. I then assigned lessons for students to independently practice on [software]. Once I felt like students were ready, I assigned a comprehension check specific to area and perimeter. Based on the results, we went over questions that majority of the class missed."* Similar to this teacher, another shared her experience of using digital mathematics software for formative assessment after teaching a lesson on operations and algebraic thinking: *"The learning target I was focusing on was operations and algebraic thinking. I looked at my [software] data to see where my students scored on the last assessment in that standard. I was able to use that data to set small groups for remediation and for enrichment."*

Interestingly also, teachers who used mathematics personalized learning software for formative assessment often found the software most useful for this very practice. According to one teacher,

"I mostly use ALEKS as a formative assessment tool for common formative assessments with teachers. It allows us to instantly know where students are at and who we need to work more with." Likewise, another teacher noted, *"The best way I utilize Mathspace is for collaboration and formative assessment…They work together collaboratively in groups, and then I can look at their data to see what immediate topics we need to address."*

Summative Assessment: Tracking Student Growth

Summative assessment—the practice of administering evaluations at the conclusion of a lesson for the express purpose of assigning students a grade that is a reflection of their knowledge—was also a less common use of mathematics personalized learning software (Schoenfeld, 2015). Additionally, teachers who noted using digital mathematics software for this practice tended not to elaborate on their experiences. According to one teacher, *"[Software] has great content in an easy to access format for pre and post assessments."* Similar to this teacher, another teacher briefly shared, *"I have only really used [software] for summative assessments."* Also, another teacher said, *"I am able to administer a PRE mastery check [using software] to my whole class, and…After 2 weeks…my students take the POST assessment and I track growth."*

Homework: More Independent Practice

Similar to pre-assessment, formative assessment, and summative assessment, teachers rarely discussed using mathematics personalized learning software for homework. Homework, as Cooper, Robinson, and Patall (2006) note, is an assignment intended to be completed by students outside of school hours for the purpose of reinforcing newly acquired skills and knowledge.

Much like Cooper and colleagues (2006) would expect, teachers who discussed using mathematics personalized learning software for homework valued the digital technology for the additional opportunity for practice that it provided students. Describing this benefit of using digital mathematics software for homework, one teacher asserted, *"I have experienced the most success with student learning involving [software] with homework…For homework, it provides [students with] experience trying to solve [problems] independently."* Similar to this teacher, another noted, *"[Software] was used as a homework assignment so students have more practice solving."* A third teacher also expressed the same sentiment, saying, *"I use [software] at home 1-2 times a week [for students] to grasp concepts taught in class."*

Interestingly, and much unlike the other instructional practices that have been discussed thus far, teachers who did not use digital mathematics software for homework often shared their reasoning and firm opinions for abstaining from the practice. Across these teachers' accounts was a shared sentiment that assigning homework with digital mathematics software was not a valid measure of student understanding as parents often completed assignments for students. According to one teacher, *"I've found success with [software, but] …never at home for homework. When they're at home, the parents are much too helpful and they progress more quickly than they truly should."* Other teachers discussed attempting to use mathematics personalized learning software for homework but quickly realizing that students never go through with completing the tasks assigned. Describing this experience, one teacher said, *"I've tried using it as homework, but the parents do not follow through and have them do it when I've*

requested." Similar to this teacher, another noted, *"Students have the option to do it for homework most nights, but students rarely complete at home."*

Supplemental Classroom Practice: Mastering New Skills

In lieu of using mathematics personalized learning software for homework, many teachers have found much success with having students practice additional mathematics problems with the device in class. As with homework, supplemental classroom exercises give students the opportunity to assess and reinforce their knowledge of concepts through additional practice. And researchers have found that this instructional exercise is increasingly being done with educational software and web applications (Parsons & González, 2018).

Among the teachers who participated in the study, a good number of them highlighted supplemental, in-classroom mathematics practice as a key reason for incorporating mathematics personalized learning software in their instruction. Discussing the role that digital mathematics software plays in providing students with more practice with newly covered mathematics concepts, one teacher said, *"I used [software] to support instruction in the class and give the students more practice on concepts."* Another teacher shared the same sentiment, however with a more concrete example about how digital mathematics software is integrated on a weekly basis in her instruction for the purposes of supplementary practice: *"My main use of [software] involves using it as an opportunity for my students to get more practice with what we have been doing and learning in the classroom. I create my own pathways each week that correlate with which standards I'm teaching…and students are given one week to complete them."*

Like teachers who utilized mathematics personalized learning software for other instructional practices, those who incorporated it in their instruction for supplementary exercises also found it to be beneficial for supporting students' learning of course material. Sharing her use of digital mathematics software for additional practice and the student outcomes she observed, one teacher said, *"When students were learning addition and subtraction with regrouping, I used [software] as a support and extension. Students were able to practice the skills they learned and some students were better able to understand it after doing the skill in [software]."* In a similar vein, another teacher alluded to the "benefit" that digital mathematics software provides to students when used for supplementary practice: *"The learning target is for the students to have additional practice with topics that have already been taught. Students are using [software] as I work with students in small groups or individually. For many students I have seen [software] to be of benefit."*

PART SIX:

TEACHER OUTCOMES

This section explores teachers' outcomes from incorporating mathematics personalized learning software in their instruction. More precisely, it investigates the impact that teaching mathematics with technology has on teachers' interest in teaching mathematics, enjoyment of teaching mathematics, and job satisfaction.

Key Findings on Teacher Outcomes

Most Teachers Were Neutral or Disagreed That Teaching Mathematics with Technology Improved Their Outcomes

Teachers who integrate mathematics personalized learning software in their instruction were asked to specify the extent to which they agree that technology use positively affected their interest in teaching mathematics, enjoyment of teaching mathematics and job satisfaction. As Figures 28-30 illustrate, most teachers do not "strongly agree" or "agree" that teaching mathematics with technology improved their teaching experiences. Put another way, teachers were less likely to indicate that they "strongly agree" or "agree" than they were to select "neutral," "disagree," or "strongly disagree" in response to survey questions about their outcomes. For example, only 44% of teachers strongly agreed or agreed that using technology in their instruction increased their interest in teaching mathematics, compared to 56% who selected "neutral," "disagree," or "strongly disagree" (Figure 28). In a similar vein, only 49% of teachers strongly agreed or agreed that teaching mathematics with technology increased their enjoyment of teaching mathematics (Figure 29), and 47% shared the same sentiment about the impact of integrating technology on their job satisfaction (Figure 30). It is important to note, however, that among teachers who did not "strongly agree" or "agree" that technology use had a positive impact on their outcomes, the vast majority felt "neutral" about its effects. In other words, teachers who did not respond affirmatively about the impact of technology on their outcomes were mostly unsure about whether it did or did not influence their teaching experiences. For example, of the 56% of teachers who did not "strongly agree" or "agree" that integrating digital technology in their instruction increased their interest in teaching mathematics, most (43%) had indicated that they were "neutral;" additionally, 11% had indicated that they disagreed and only 2% noted that they strongly disagreed (Figure 28).

Figure 28. Teachers' Views About Whether Technology Integration Increased Their Interest in Teaching Mathematics

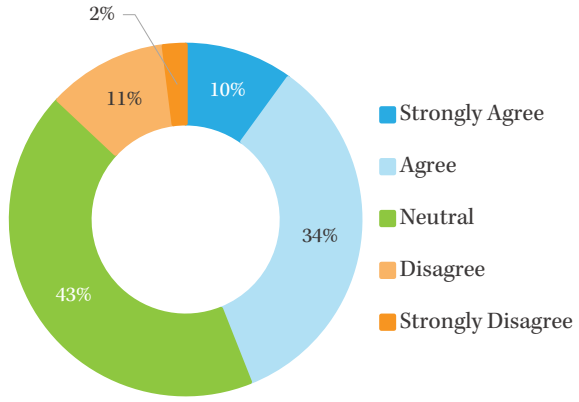


Figure 29. Teachers' Views About Whether Technology Integration Increased Their Enjoyment of Teaching Mathematics

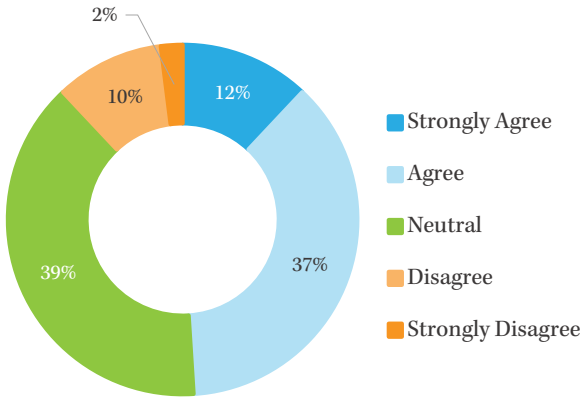
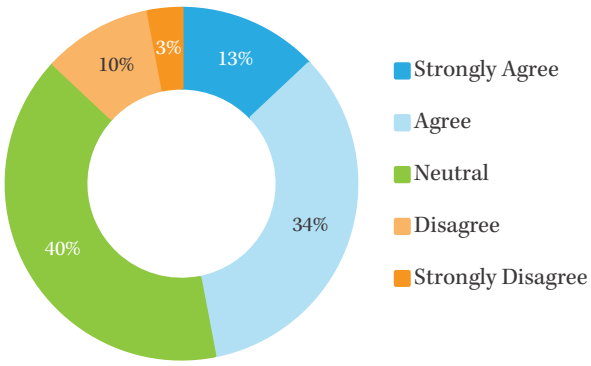


Figure 30. Teachers' Views About Whether Technology Integration Increased Their Job Satisfaction



PART SEVEN:

CONCLUSIONS AND CONSIDERATIONS

Drawing from two data sources—a survey and an interview protocol—this evaluation report investigated key areas of interest related to teaching mathematics with technology in Utah. More specifically, the report addressed the demographics, knowledge, practices, and outcomes of mathematics teachers in Utah who integrate digital software in their instruction. This section provides an overview of the report's main findings in relation to the aforementioned topics. It also provides considerations for the K-12 Math Personalized Learning Software Grant Program that are informed by the evaluation's findings, relevant research, and program objectives.

Summary of Findings

Demographics

The current examination of mathematics teachers in Utah who utilize digital software in their instruction reveals the practice to be somewhat widespread given the varied school districts and schools to which teachers who participated in the study are affiliated. Teachers who use mathematics personalized learning software in their instruction, as findings also suggest, primarily teach the 3rd, 4th, and 5th grades although they tend to more frequently integrate digital mathematics software in their instruction of middle school and high school mathematics courses, particularly grade 8 mathematics, secondary math I, and secondary math II. As it concerns other demographic attributes such as gender, degree attainment, and endorsements, the vast majority of teachers who participated in the evaluation identified as female, reported holding an education degree but not a mathematics one, and working towards a variety of endorsements, of which "other" endorsements was the most selected option followed by "mathematics" endorsements.

Teacher Knowledge

Informed by the TPACK framework, developed by Mishra and Koehler (2006), survey questions pertaining to teacher knowledge were designed to understand the extent to which mathematics teachers in Utah who use digital technology in their instruction possess content knowledge, pedagogical knowledge, pedagogical content knowledge, technology knowledge, technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge. As findings indicate, the majority of teachers responded affirmatively (i.e., indicated that they strongly agree or agree) to possessing the aforementioned key forms of knowledge. At the same time, however, a lower majority of teachers indicated that they possess technology knowledge and the most robust form of knowledge, technological pedagogical content knowledge.

Teacher Practices

In relation to instructional practices with technology, teachers were asked how often they use technology for in-classroom and out-of-classroom assignments, how effective digital technology is for key instructional practices, and how technology best supports teaching and learning in their classrooms. As findings from the evaluation reveal, teachers more frequently use digital mathematics software for in-classroom activities than for out-of-classroom assignments. Additionally, they find technology to be most effective for instructional practices that emphasize the individual needs of students (i.e., differentiation, remediation, and enrichment) than those that do not require explicit distinction to be made between students (i.e., pre-assessment, formative assessment, summative assessment, homework). Relatedly, teachers also more frequently discussed that technology best supported teaching and learning in their classrooms through facilitating differentiation, remediation, and enrichment practices.

Teacher Outcomes

Finally, mathematics teachers were queried about the impact that employing technology in their instruction had on their outcomes, particularly their interest in teaching mathematics, enjoyment of teaching mathematics, and job satisfaction. Findings indicate that only a minority of teachers (i.e., less than 50%) strongly agree or agree that teaching mathematics with technology positively affected their outcomes. Additionally, among the teachers who did not respond affirmatively about the impact of technology on their experiences, most indicated that they were "neutral;" in other words, they could not answer one way or another about its effects.

Considerations for the K-12 Math Personalized Learning Software Grant Program

Provide Content- and Technology-Specific Professional Learning to Mathematics Teachers Who Teach with Technology

As discussed in Part 3 of the report, only 6% of mathematics teachers who participated in the study hold a degree in mathematics. Additionally, findings from Part 4 reveal that teachers were less likely to strongly agree or agree that they possess technology knowledge—knowledge of the different mainstream and digital technologies that can be employed in teaching—and technological pedagogical content knowledge—knowledge that facilitates a thoughtful integration of content, pedagogy, and technology and is regarded as the most robust and effective form of knowledge for teaching with technology. To be sure, these findings are no different from those that have been noted in extant literature. Historically and contemporarily, researchers have found that U.S. K-12 mathematics teachers often lack the subject matter expertise in mathematics—because of the generic teacher education they receive—to facilitate students' deep understanding of the subject (Hossain & Robinson, 2012; Jensen et al., 2016). Additionally, those who employ digital software in their instruction are often poorly informed about how to effectively use technology to teach particular mathematics content and use it more often for low-level tasks (DeCoito & Richardson, 2018; Gonzalez & González-Ruiz, 2017; Urbina & Polly, 2017). To support mathematics teachers in providing high-quality mathematics instruction, research suggests providing teachers with professional learning that emphasizes content and pairing them with "mathematics specialists" that can serve as coaches or mentors (Campbell & Malkus, 2013; Swars et al., 2014). Additionally, given mathematics teachers' use of technology in their instruction, it is important that the professional learning they receive showcases ways to effectively select and incorporate technology in teaching different mathematics topics (Hechter & Vermette, 2014). The STEM Action Center could consider partnering with the Utah Education Network (UEN) to provide professional learning to mathematics teachers.

Establish an Online Forum for Mathematics Teachers to Share and Learn Effective Practices for Integrating Digital Mathematics Software in Instruction

In addition to providing professional learning opportunities to teachers, another useful avenue to encourage teachers' effective use of technology in mathematics instruction may be to create an online forum where teachers can congregate virtually to share and learn effective practices from each other. This resource may be particularly beneficial in light of the national state of emergency posed by the COVID-19 pandemic and the more general switch from in-person to distance learning.

Explore the Quality of Technology Integration in Classrooms with Access to Digital Mathematics Software

While the current evaluation identified the various ways in which mathematics teachers use digital software in their instruction—including for differentiation, remediation, enrichment, pre-assessment, formative assessment, summative assessment, homework, and supplemental practice—it did not investigate the *quality* of technology integration for these purposes. As Puentedura (2013) suggests, student learning is mostly impacted and improved when technology is used in transformative ways, such as to significantly re-design tasks or to create new tasks that would otherwise be impossible without the use of technology. For the most part, as other scholars have indicated, K-12 mathematics teachers rarely use technology in transformative ways. Instead, the more standard practice among mathematics teachers is to assign technology-based tasks to students that require low-level computations and that poorly reflect the educational potential of the technology (DeCoito & Richardson, 2018; Gonzalez & González-Ruiz, 2017; Urbina & Polly, 2017). Given the aforementioned findings from relevant literature and discussion in the paragraph above—that highlights the need to support mathematics teachers' acquisition of subject matter knowledge, technology knowledge, and technological pedagogical content knowledge—it may be worthwhile to also examine the quality of tasks that teachers assign with mathematics software to understand if they are integrating technology in ways that would be deemed highly effective.

Provide A Repository of Model Mathematics Lessons That Effectively or Transformatively Integrate Digital Mathematics Software

As a more proactive step, given the aforementioned findings from research that teachers tend not to use digital mathematics software in transformative ways, it may be useful to create and make available an online repository of mathematics lessons that effectively integrate digital mathematics software. Following the creation of such a resource, it may be useful to disseminate it widely at participating schools and encourage mathematics teachers to adopt or adapt lessons from the repository for their instruction.

Organize Virtual Coaching to Educate Teachers on How to Effectively Integrate Technology for Pre-Assessment, Formative Assessment, Summative Assessment, and Homework

Findings from the evaluation suggest that teachers are much less likely to use mathematics personalized learning software for pre-assessment, formative assessment, summative assessment, and homework than they are to use it for differentiation, remediation, and enrichment. It is not necessarily constructive to immediately encourage teachers to use digital mathematics software more frequently for the former purposes. Rather, it may be more helpful that they are first provided with educated guidance on how *best* to use technology for these instructional practices. This professional development opportunity may be provided in the form of virtual coaching because of the COVID-19 pandemic.

Provide Mathematics Teachers with Enough Digital Mathematics Software to Support One-to-One Learning

Research has found that transformative or higher-order use of technology is difficult, if not impossible, in classrooms where each student does not have access to their own digital device (Donovan, Green, & Hartley, 2010). Additionally, studies have also found that students in one-to-one classrooms use technology more frequently and for various learning purposes, experience higher satisfaction with technology, demonstrate greater technological competence, and perform better in mathematics (Lei & Zhao, 2008; Oliver & Corn, 2008; Zheng, Warschauer, Lin, & Chang, 2016). Given the overarching goal of the K-12 Math Personalized Learning Software Grant Program to improve student outcomes in mathematics and prepare them for college mathematics courses, it is important that consideration is given to acquiring enough digital software to support one-to-one learning in mathematics classrooms.

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