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Research Article

The Impact of COVID-19 on Teachers' Integration of Digital Technology

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ABSTRACT

The coronavirus pandemic impacted all aspects of society, causing countries and local communities to close workplaces, move schools to remote instruction, limit in-person contact, cancel public gatherings, and restrict travel. Attempts to mitigate COVID-19 through remote instruction provided unique opportunities for researchers to examine the resources teachers utilize to drive their practices. We examine the impacts of the pandemic on grades 6-12 mathematics teachers and math interventionists, with particular attention to teachers' integration of digital resources. Using purposive sampling, we surveyed 50 participants—across urban, suburban, and rural districts—throughout the United States. The descriptive survey focused on six aspects of teachers' practices with digital resources. Results indicate that challenges encountered and lessons learned included a lack of student engagement and motivation, increased distractions, and varied access to technology. Integration of technology did not positively impact students' mathematical proficiency across all teachers. Common resources used across planning of lessons, implementation of instruction, and assessment included the Google platform, Desmos, and GeoGebra. Where appropriate, we situate our results within the larger context of recent international research. These findings support teacher practices that constantly attempt to optimize students' mathematics and social emotional learning, regardless of the environment or situation.

Keywords: digital technology, remote instruction, teachers' mathematics practices, students' social emotional learning

INTRODUCTION

On April 2, 2020, over 1,598,099,000 learners worldwide (91.3% of total enrolled students), from pre-primary through tertiary education, were impacted by school closures as a result of the novel coronavirus (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021)). According to the United Nations Children's Fund (2021), "In the period between March 11, 2020, and February 2, 2021, schools have been fully closed for an average of 95 instruction days globally, which represents approximately half the time intended for classroom instruction" (p. 3).

The COVID-19 pandemic forced schools to adapt to fulfil their many functions, challenging teachers to rethink ways to support their teaching and their students' learning. Countries attempted to fill the void left by school closures by offering a variety of distance learning solutions, including "hi-tech alternatives like real-time video classes conducted remotely to lower-tech options such as educational programming on radio and television" (UNESCO, 2020, para. 3). According to the Organisation for Economic Co-operation and

Development (OECD, 2020), an almost universal response to the pandemic was the use of digital technologies to support teachers, students, and their families. Digital technology allows for new solutions to "what people learn, how people learn, where people learn and when they learn. Technology can enable teachers and students to access specialized materials well beyond textbooks, in multiple formats and in ways that can bridge time and space" (OECD, 2020, para. 2). Unfortunately, not all students have the same access to digital devices and online resources, and access varies greatly across and within countries (OECD, 2020). As a result, the pandemic has highlighted and exacerbated existing inequities in education, with the most vulnerable children being the most adversely affected.

Rothstein (2020) asserts, "The COVID-19 pandemic will take existing academic achievement differences between middle-class and low-income students and explode them" (para. 5). Disparity across schools and school districts arise from several factors, including the fact that lower-income students are "less likely to have access to high-quality remote learning or to a conducive learning environment, such as a quiet space with minimal distractions, devices they do not need to share, high-speed internet, and parental academic supervision" (Dorn et al., 2020, para. 12).

In the United States, remote learning continued not only throughout the remainder of the 2019-2020 academic year, but also well into, if not all, the 2020-2021 academic year for many students. In this report, we examine the affordances and constraints of using digital technologies in grades 6- 12, particularly throughout the covid pandemic, and their potential for the improvement of mathematics teaching and learning. The study addresses the following research question: How has the necessity for remote and hybrid teaching and learning environments, due to the ongoing coronavirus pandemic, impacted grades 6-12 mathematics teachers' practices?

METHODS

Clark-Wilson et al. (2011) define digital technologies as "a wide range of devices which combine the traditional elements of hardware (processing, memory, input, display, peripherals) and software (operating system and application programs) to perform any one of a given range of tasks" (p. 10), including technical, communications, consumer, and educational applications. In this report, we use the term resource in the sense of Adler (2000), who defines a resource as anything likely to 're-source', or "to source again or differently" (p. 207), the teacher's work. Therefore, a digital resource refers to any digital technology that is 'developed and used by teachers and pupils in their interaction with mathematics in/for teaching and learning, inside and outside the classroom' (Pepin & Gueudet, 2020, p. 172-173), including electronic tools, systems, devices, apps, software, programs, websites, digital textbooks.

In this report, we examine the effects of the coronavirus pandemic on grades 6-12 mathematics teachers and math intervention specialists, with particular attention to teachers' integration of digital resources. The study was conducted using purposive sampling, based on identification of those populations the research team judged would provide information productive to addressing the study's research questions. As such, the research team searched online for the email addresses of grades 6-12 mathematics teachers and math intervention specialists from across the United States. Potential participants were then sent an email inviting them to participate in the survey, followed by a reminder email invite five days later. Email invites were sent to 1,650 teachers in the U.S. state of Ohio (the researchers' home state) and between 150-250 teachers and interventionists—across urban, suburban, and rural districts—in each of the remaining 49 U.S. states. In total, the research team emailed over 11,450 survey invites to grades 6-12 mathematics teachers and math interventionists across the United States.

The descriptive survey included 13 questions and focused on the following six aspects of teachers' (and their students') work with/on digital resources (e.g., electronic tools, systems, devices, apps, software, programs, digital textbooks, and websites):

1. Challenges teachers and their math students encountered regarding the use of digital resources over the course of the pandemic.
2. Lessons learned regarding teachers and their math students' use of digital resources over the course of the covid pandemic.

3. The digital resources teachers use to prepare lessons; during instruction; and to design, create, and/or administer assessments.
4. The ways that integration of digital resources into the mathematics curriculum has impacted the mathematics proficiency and performance of teachers' math students (and the resources involved).
5. The digital resources teachers utilize to support their students' social and emotional learning.
6. Comparisons of the percent of time teachers typically spent prior to covid, and currently spend, using digital resources when engaged in various practices (e.g., preparing lessons, grading, or marking student work).

A total of 50 teachers completed the survey, a survey response rate of 0.44%. Forty-six of these participants identified as math content teachers, one participant identified as a math interventionist, and three respondents identified as both a math content teacher and an interventionist. Participants' years of experience were distributed across the following levels: First year teacher: three participants; 2-5 years: seven participants; 6-10 years: seven participants; 11-15 years: nine participants; 16-20 Years: six participants; 21-25 years: seven participants; and more than 25 years: 11 participants. Finally, the grade level(s) of the students taught by each participant is provided in **Table 1**.

Table 1. Grade levels taught by participating teachers

Grade level	Grade 6	Grade 7	Grade 8	Grade 9	Grade 10	Grade 11	Grade 12
Number of teachers	11	11	17	18	17	20	17

Twenty-two participants teach students from only one grade level, with 10 participants only teaching students in grade 8. For the 28 participants who teach students from multiple grade levels, seven taught students from grades 9-12 and one teacher taught students from each of grades 7-12.

Recent research (e.g., Bushweller, 2022; Rauf, 2020) has shown a significant increase in the number of one-to-one schools and districts over the course of the pandemic; that is, environments where all students in a school or district are provided with their own laptop, netbook, tablet, or other mobile-computing device. According to the EdWeek Research Center (2022), "Eighty-five percent of teachers, principals, and district leaders say all the students in their classrooms, schools, and districts have a school-issued digital device, such as a Chromebook or an iPad" (p. 3). Teachers of the research reported here failed to exhibit such characteristics, with only four participants indicating they taught at one-to-one schools. Participants were also asked to identify the digital resources they utilize to prepare lessons, during instruction, and to design, create, and/or administer assessments. **Table 2** illustrates the general digital resource types and specific examples participants indicated they utilized for each of these three practices.

As illustrated in **Table 2**, there was quite a lot of overlap between the digital resources teachers utilized to prepare lessons, during instruction, and to create and/or administer assessments. In addition, these resources may be partitioned into 18 types, based on the specific use(s) of the resource, such as screen and video recorder; learning platform; web-based graphing calculator; student Chromebooks; SMART board interactive display; and formula editor and equation writer.

Although participants were not directly asked to identify the type(s) of professional learning they had received related to each of the digital resources listed in **Table 2**, nor asked to identify the type(s) and frequency of their students' training with these same resources, several teachers identified a lack of professional development for themselves and training for their students as a major challenge they and their students encountered over the course of the pandemic. Sample teacher responses highlighting these issues are described in the *Results* section below.

Analysis involved "a process of conceptual abstraction by assigning general concepts (codes) to singular incidents in the data" (Vollstedt & Rezat, 2019, p. 86) to generate and test grounded theory, as described by Corbin and Strauss (2014). The grounded theories we built during ongoing analysis of teachers' survey responses were models of teachers' understandings of the digital resources they utilized and teachers' rationales for such utilizations, throughout and beyond school closures. Throughout our analysis, we engaged in open and axial coding to construct a grounded theory (Corbin & Strauss, 2014).

Table 2. Digital resource types utilized by participating teachers

Practice	Digital resource type (example)
Preparing lessons	• Screen and video recorder (e.g., Kami, Loom, Screencastify, Smart Recorder) • Online video sharing platform (YouTube) • Digital textbook (e.g., Big Ideas Math) • State assessment questions (e..g., AIR, PARCC) • Web-based graphing calculator (Desmos, GeoGebra) • Web-based activities (e.g., Delta Math, Desmos Classroom Activities, Go Formative, Kahoot, Quizizz) • Problem generator (Kuta Software) • Learning platform (e.g., ALEKS, Canvas, Google Classroom, IXL, Khan Academy, Nearpod, Savvas, Schoology, SMART Notebook, WebAssign) • Online resource marketplace (e.g., Teachers Pay Teachers) • Interactive video lessons (Edpuzzle)
During instruction	• Screen and video recorder (e.g., Kami, Screencastify) • Online video sharing platform (YouTube) • Digital textbook (e.g., Reveal Math) • Web-based graphing calculator (Desmos, GeoGebra) • Web-based activities (e.g., Delta Math, Desmos Classroom Activities, Gimkit, Gizmos, Go Formative, Kahoot, Prodigy, Quizizz, Quizlet, Reflex) • Learning platform (e.g., ALEKS, Canvas, DreamBox, Google Classroom, IXL, Khan Academy, Mathia, Nearpod, Savvas, Schoology, SMART Notebook) • Interactive video lessons (Educreations) • Web-based Google docs editors suite (Google Docs, Google Forms, Google Sheets, Google Slides) • Students' Chromebooks • SMART board interactive display • Handheld calculators (e.g., TI-84 Plus) • Digital projector (e.g., Elmo) • Teacher iPad
Creating and/or administering assessments	• Digital textbook (e.g., Big Ideas Math, Reveal Math) • State assessment questions (e.g., Smarter Balanced Assessment System) • Online assessment (Edulastic, NWEA Measures of Academic Progress [MAP] test) • Web-based graphing calculator (Desmos, GeoGebra) • Web-based activities (e.g., Delta Math, Gizmos, Go Formative, Illustrative Math) • Problem generator (Kuta Software) • Learning platform (e.g., ALEKS, Canvas, Go Math!, IXL, iReady, Khan Academy, Schoology) • Interactive video lessons (Edpuzzle) • Web-based Google docs editors suite (e.g., Google Docs, Google Forms) • Formula editor and equation writer (Equation editor–Microsoft, MathType)

RESULTS

The results section will be divided into six subsections, each focused on one of the aspects of teachers' (and their students') work with/on digital resources described above. Where appropriate, we situate our results within the larger context of recent international research.

Challenges Teachers and Their Math Students Encountered Regarding the Use of Digital Resources Over the Course of the Pandemic

Open and axial coding of teachers' responses to a survey question asking participants to describe the biggest challenges they and their math students encountered regarding the use of digital resources (e.g., electronic tools, systems, devices, apps, software, programs, digital textbooks, websites) over the course of the pandemic, resulted in five main themes, each described in more detail below.

Issues with internet access and/or internet-enabled devices

Seventeen teachers (34%) indicated one of the biggest challenges they and their math students faced over the course of the pandemic involved issues with the internet (or Wi-Fi) access and/or issues with devices enabled for internet access. Sample responses included:

1. "[T]he biggest problems were . . . just not having . . . Wi-Fi or a good computer."
2. "[T]he biggest issue would be just internet issues . . . just spotty Wi-Fi and sometimes it's mostly reliable, but there were [and] are some days where it's really, really, slow or you know, what we want to do is just totally not working."
3. "Accessibility issues are always a big one, for students and teachers alike."
4. "[A] lot of our kids do not have Wi-Fi at home, do not have . . . access to . . . the Internet unless they use their phone, which is not always conducive to trying to do textbook work on the smaller screens."

This result aligns with recent research in the United States. According to McClain et al. (2021), "Overall, about a third (34%) of all parents whose children's schools closed at some point say their children have encountered . . . tech-related issues" (para. 22). Such issues include the inability to complete schoolwork due to lack of computer access at home, having no reliable [Wi-Fi] connection at home, and having to do schoolwork on a cell phone (McClain et al., 2021). Global findings are even more troubling. According to the United Nations Children's Fund and International Telecommunication Union (UNICEF & ITU, 2020), "More than two-thirds of school-age girls and boys aged approximately 3 to 17 years (1.3 billion children) and 63 per cent of youths aged 15 to 24 years (almost 760 million youths) lack internet access at home" (p. 2).

The challenges of access to the Internet and internet-enabled devices also prompted teachers to focus on notions of inequity in their responses. Sample responses indicating such a focus include:

1. "[I]nequity of digital resources. Some students have access to ultra-high-speed internet as well as new smartphones, laptops, and tablets."
2. "Many teachers, myself included, could not afford to buy ourselves new equipment or pay monthly fees for high speed Internet and resorted to borrowing out-of-date school laptops and installing and paying for our own home Internet service."
3. "[I]t was inequitable because some schools have PTAs (Parent Teacher Associations) that were able to purchase more things than other schools where . . . the socio-economic background of students is different, and their PTA may not have as much income and may not be able to buy as many subscriptions to programs such as IXL or DeltaMath or . . . Formative."

Issues of inequity during the pandemic have been a common theme among several recent studies and documents. For example, results from McClain et al. (2021) found that "children from [U.S.] households with lower incomes . . . have been especially likely to encounter tech-related obstacles in completing their schoolwork" (para. 21). Such results follow a similar trend globally, where only 74% of the poorest households in high-income countries have internet home access, compared to 97% of the richest households (UNICEF & UTI, 2020, p. 2).

Participating teachers' descriptions of socioeconomics and inequity were not isolated to the Internet, devices, apps, and platforms. Rather, issues involving familial constraints and students' learning spaces were also discussed. For example:

1. "[T]he socio-economics that we cannot do anything about, if you have a house full of younger brothers and sisters, even if you . . . make time to meet with the math teacher at a specific time and specific date, it does not always work, it's too loud . . . You have to babysit . . . specifying the time did not work for me."

2. "Families had a variety of devices, internet connection types, and private space options. As a result, some students had a much less productive experience each day in class."

Although recent reports indicate older siblings served as a source of support for younger siblings (e.g., Meinck et al., 2022), such situations also frequently served as distractions, not only for older siblings—as illustrated above—but for all students in that "devices may need to be shared among parents and siblings, impeding many students from following lessons during school closures" (OECD, 2021, p. 5).

Lack of student engagement, motivation, or accountability

Ten teachers (20%) indicated their students' lack of engagement, motivation, or accountability as a big challenge during the pandemic. Sample responses included:

1. "[E]ven when I do a Google Meet and I am there to answer questions, a lot of students just lack the motivation to join. So, I think our biggest challenge has just been on the days when we are virtual, students do not want to join because they lack . . . motivation."

2. "[T]he biggest challenge would be just keeping them engaged . . . we might find a new . . . digital resource and they might be really interested in it. But if I do it too often, they're bored of it and I lose their attention and I have to find another resource . . . And even though they might really, really like it, if I do it twice in one week, they do not want to do it anymore."

3. "The biggest challenge I faced was a complete lack of engagement with anything related to school."

4. "The biggest challenge . . . during the pandemic was when we were teaching our students remotely and they had to log in each day and . . . [I needed] to be able to know that they were actually paying attention or not paying attention. Whichever the case might have been, I had no idea. Because oftentimes, if their camera was on it was pointed at the ceiling and not at them, or if their camera was on pointed at them, they were muted. And you could tell that they were talking to somebody else and not paying attention . . . so, that was one of the biggest challenges . . . the engagement aspect."

5. "[T]he biggest issues or challenges for the students . . . was . . . their attention span. It's so easy for them to not view it as . . .school . . . [and] a lot of the students tried to lay down on their beds and I had a couple of students who would actually turn on the video and then fall back asleep on their bed."

These results align with recent research by Al Salman et al. (2021) involving secondary students in Jordan. According to Al Salman et al. (2021), the great decrease in the speed of the Internet during students' distance learning resulted in "boredom, demotivation and negative attitudes towards learning" (p. 67). Furthermore, such challenges have been a theme across several studies globally, including Canada (DeCoita & Estaiteyeh, 2022), Indonesia (Mailizar et al., 2020), Singapore (Tay et al., 2021), and Turkey (Hebebci et al., 2020).

Aligned with students' lack of engagement and accountability is an increase in cheating, a challenge reported by three participating teachers. These three teachers asserted:

1. "The biggest challenge I face is having all of my students trying to cheat on their online work. Students have found websites that just give them the answers."

2. "[Students] just are not mature enough to handle all the responsibility that comes with having, you know, the world's information at your hand . . . there's so many students that are using it to cheat."

3. "[T]here's so many ways to cheat with math and technology."

Neither the issue of cheating nor using the Photomath app or "Googling" a math problem to support cheating are unique to the teachers in the study reported here or to students in the United States. Cheating throughout the pandemic is also not limited to pre-tertiary math students. According to Lancaster and Cotarlan (2021), the number of tertiary student requests on the Chegg online file sharing site posted by students in five STEM subjects "increased by 196.25% comparing the time period April 2019 to August 2019 with the period April 2020 to August 2020" (p. 2)—a period of time corresponding to when many courses moved to online delivery and assessment. Recent research has also identified an increase in cheating in Canada (DeCoito & Estaiteyeh, 2022), Germany (Janke et al., 2021), and Spain (Comas-Forgas et al., 2021) over the course of the pandemic.

Finally, the lack of accountability indicated above corresponded with a lack of respect for materials (e.g., internet-enabled devices), with two participating teachers indicating:

1. "When covid hit, the Chromebooks went home with the students. Unfortunately, a lot of families did not take care of them. Some of them were stolen, some just destroyed . . . And now that we're coming back to more in-person, learning technology is lagging behind again because the resources we had and gave to the students are not being returned or when they are being returned, they're just not in usable condition."

2. "We have so many students show up without Chromebooks, without chargers, with a Chromebook that's about to die . . . seriously we have over 1000 missing Chromebooks and we have no more chargers for the students."

Issues with students' inability to show their work and teachers' attempts to provide feedback using digital resources

Eight teachers (16%) identified issues with students' inability to show their work and teachers' attempts to provide feedback using digital resources as a big challenge. Sample responses included:

1. "I think the biggest challenge was just trying to do math digitally . . . there were no digital resources that I could really find that would allow us to do math in some other way that did not involve the paper, paper pencil. But to me there was really no way around that."

2. "[M]ostly, no way to show work on digital platforms."

3. "[W]e had students turn things in over [Microsoft] Teams but grading math over Teams, it's kind of hard to type an explanation . . . quickly [for] things that involve fractions."

4. "There are some issues with how to type math responses in a word processing program. Even with the Desmos Activity Builder, which is designed for math, there are some issues with entering fractions."

5. "I never had a really good gauge of what students knew and could . . . demonstrate that they knew . . . my students . . . struggled with that . . . I ended up having them show all their work on paper, taking pictures so that I could provide them with feedback in a timely manner."

Unless schools were able to provide each math student with a tablet and stylus (or tablet pen), students were left showing their work (i.e., their thinking and reasoning) on paper, then submitting this document to their teacher via an image (e.g., JPEG, PNG) or Portable Document Format (PDF). Alternatively, many teachers moved to assessing their students via an online assessment platform that allowed for little, if any, student work (e.g., Edulastic, IXL). Recent research by Courtney (2022) of a small sample of pre-tertiary mathematics teachers from rural areas in the United States found that 55.6% of teachers began (during school lockdowns) and continue to provide feedback in modes other than, or in addition to, handwritten comments, including audio comments (via Mote voice messaging Chrome extension or Vocaroo voice recording service) and video commentary (via Flipgrid, Screencast-O-Matic screen capture tool, or Awesome Screenshot screen recorder Chrome extension).

Providing students with feedback proved to be another challenge. According to Meinck et al. (2022), "The transition to remote learning, confronted many teachers with challenges regarding how feedback on their students' schoolwork would be provided" (p. 92). In fact, issues providing sufficient feedback to students throughout the pandemic is a challenge cited by several researchers (e.g., Al Salman et al., 2021; Cárdenas et al., 2022; Fakhrunisa & Prabawanto, 2020; Reimers, 2022).

Issues with increased distractions due to increased use of digital resources

Three teachers identified increased distractions as a big challenge. Sample responses included:

1. "[S]tudents are constantly distracted. They have cell phones 24/7, they're listening to music 24/7 . . . So, the digital resources do not really help because it just gives them more access to distraction."

2. "[S]tudents did not always listen when they were on online lessons; they'd be distracted by video games or various other things that they could do at home . . . that they ca not do in a classroom while they're here."

3. "[C]ertain things have been blocked by the district. But Gmail has not been blocked . . . and we do not allow them to carry their phones . . . But now with the Ipad, I mean they just basically have their phone all day long."

4. "[W]e should be able to monitor everybody's Ipad while they're in our classroom . . . but it never works . . . I know some kids are watching YouTube videos. I know some kids are playing games. I mean I'm walking around as much as I can and trying to give them meaningful activities, but it still happens and that is a pretty big challenge especially for kids who are just addicted to it. And even when I talk to them one-on-one, like sometimes they just admit that they are so addicted to it and . . . that's what they're doing all day long."

The increase in use of digital resources has been accompanied by an increase in screen time. According to McClain et al. (2021), "About seven-in-ten parents with children in kindergarten through 12th grade (72%) say their children were spending more time on screens as of the April (2021) survey compared with before the outbreak" (para. 25). This increase in screen time has been further exacerbated by changes in family rules around the use of digital devices. McClain et al. (2021) assert that approximately "39% of parents with school-age children say they have become less strict about screen time rules during the outbreak" (para. 25). Such factors seem likely to contribute to the increased distractions reported here.

Lack of professional development for teachers and training for students in the use of digital resources

Three teachers identified the lack of professional development for teachers and training for students in the use of digital resources as a big challenge. Sample responses included:

1. "We have not been trained on these digital resources. We're told that they're available, we're told to use them. We were told that they were there to help us learn. But for the most part, we were not told how to use them. We were not shown how to use them, and we do not know how to use most of them."

2. "It was hard for me to learn how to navigate the new technologies and learning systems we were required to use. It was a real learning curve for me and the students."

3. "Students really are not adept at using technology. I had to teach my high schoolers how to add attachments, send emails and use basic technology."

Students' lack of experiences with and preparation for online learning has been examined by recent research across the globe. According to Al Salman et al. (2021), in Jordan:

> students were not psychologically ready or skilled for the sudden, complete transformation in receiving education in all courses at home. They were not ready and did not have the skills to use distance learning platforms. For many of them, it might have been their first experience in using technology for learning (p. 65).

Regarding teachers, the lack of professional development in the use of digital resources was not unexpected. According to van der Spoel et al. (2020), the pandemic was a unique situation, one where educators were "forced to start teaching remotely within a short time span, even though most educational institutes, their digital learning environments, and their support systems were not fully ready" (pp. 623-624). As such, preparation and delivery were "an individual or team effort without . . . sufficient expertise and support available" (van der Spoel et al., 2020, p. 624).

Lessons Learned Regarding Teachers and Their Math Students' Use of Digital Resources Over the Course of the COVID Pandemic

As the world changed as a result of the pandemic, education was forced to adapt. Along with innovation and changes in how education was distributed and received, particularly in terms of digital technology, came a learning curve for both teachers and their students. In response to a survey question asking participants to describe "lessons learned" regarding their own and their math students' use of digital resources over the course of the pandemic, teachers in this study reported significant variation in how instruction was distributed, and student learning was assessed, including differing expectations and a plethora of available resources. Many of the roadblocks participating teachers encountered regarding their students, included lack of interest, decreased motivation, and different learning styles. Students also had varying access to technology and Wi-Fi capabilities. Participating teachers shared that they had to adapt the technology to meet the needs of each student, which often included having a back-up plan. Even if technology was available, students were easily distracted due to constant stimulation from online material. There were a seemingly infinite number of resources, but there was not a one-size-fits-all model. Teachers also focused their attention not only on teaching technology skills but implementing mathematics skills within the technology.

One participating teacher asserted that while "digital resources have their place, nothing can take the place of the teacher." In this statement lies a primary response of teachers regarding what they have learned through the integration of technology—the successful implementation of technology-based learning relies on the teacher first, followed by the technology used. Technology must be used situationally, realizing that overuse and overstimulation can cause student burnout. Finally, technology must be supplemental and used primarily as an enhancer of the existing curriculum.

The Digital Resources Teachers (And Their Students, if Applicable) Use to Prepare Lessons; During Instruction; And to Design, Create, And/or Administer Assessments

Although the types of resources participants used to plan lessons, during instruction, and to create and/or administer assessments were documented in **Table 2**, in this section we elaborate on the specific resources teachers utilized for each practice. In planning for instruction, many teachers indicated the Google platform played a significant role in their lesson preparation, most specifically Classroom, Slides, and Docs. One common emphasis was the development of HyperDocs, which are media-infused, interactive Docs or Slides. Within Google Classroom, teachers could create and assign work for their students. According to participating teachers, many students would take the PDF that was uploaded by their teacher and work, in conjunction with the Kami online document annotation and markup tool, to make editable PDFs. Thus, follow-up submissions (or re-submissions) were much simpler than traditional paper and pencil, with follow-up PDFs created to re-submit.

Respondents also identified screen casting as a primary source of technological preparation for their digitally delivered lessons. The primary resources used were Edpuzzle, Khan Academy, YouTube, and teacher-recorded videos. Screen casting is the process of creating or sharing content via a video recording. According to Thomas (2017), "screen casting captures audio from those using the app as well as video of what is written or presented on the screen" (p. 494). Methods of screen casting varied among participants. Some teachers preferred finding videos from online resources, such as YouTube, Khan Academy, Edpuzzle, or other

reputable educational producers, to infuse into their content. Other teachers recorded lessons live in their classrooms or recorded and edited a video outside of class. An additional option utilized by participating teachers included uploading a video to Edpuzzle, where they inserted formative questions throughout the video and assigned the video (and embedded questions) to their students. Teachers indicated that an advantage to Edpuzzle is the accountability it provides. Teachers can track student progress in real time, including the student's video viewing and question answering. Additionally, teachers indicated they located videos that have already been created and utilized these to their advantage. According to participating teachers, some of the many ways that screen casting benefits their students include: a re-teaching tool, a flipped classroom, a resource for absent students, a remote learning tool, and a way to hold students personally accountable. Additional methods of distribution of remote instruction identified by teachers included video-presentation platforms, like Zoom, Google Meet, and Microsoft Teams.

There were many crossovers between digital resources that teachers used in the preparation of lessons and in the integration of instruction. In preparing lessons, participating teachers created games and activities using applications like Quizlet, Kahoot, NearPod, IXL, and Google Forms. Then, they implemented those games as part of instruction, where students used the apps to master mathematics concepts. Participating teachers also cited an increased use of online applications such as Delta Math, Khan Academy, and Open Math. Finally, teachers indicated an increased use of their digital textbook, provided by learning systems such as Big Ideas Math, McGraw-Hill, and Pearson. Regarding specific mathematics technology, participating teachers primarily used Texas Instruments, Desmos, and GeoGebra for graphing calculators. Teachers' responses indicated that some form of graphing interface was necessary for visualizing graphing concepts; specifically in Geometry and Calculus. There was also a learning curve for teachers in preparing lessons; specifically for lessons that integrated Desmos and GeoGebra; although most teachers reported proficiency in using Texas Instruments software.

Teachers reported a wide variety of tools used to create assessments. Tools, such as Kuta Software or EdPuzzle, included pre-made test banks or question generators. Other resources, such as Schoology and Edulastic, use a variety of formats to mimic standardized tests. Some tools, including Kami or Google Docs, allow for multiple ways to respond to a variety of question types. Tools such as Canvas or Google Forms, have integration with digital gradebooks and can interact with other digital tools. In addition, many publisher tools come packed with digital texts, such as McGraw Hill and Savvas. Finally, tools such as Quizizz or Gimkit offer a game-like assessment platform. Despite these extra features, the majority of respondents said they preferred to use paper and pencil to administer assessments even when such assessments were designed using a digital tool. One reason given for the choice to avoid digital assessment was that "more hands on or paper and pencil opportunities are more effective in helping my students think through their math."

The Ways That Integration of Digital Resources Into the Mathematics Curriculum Has Impacted the Mathematical Proficiency and Performance of Teachers' Students

In general, in response to a survey question asking teachers to describe the ways integrating digital resources into the mathematics curriculum had affected the mathematical proficiency and performance of their students, participants indicated students' mathematical proficiency either decreased or stayed the same. Some teachers reported their students demonstrated an increased desire to complete a task, but not to acquire the knowledge and skills needed to master the task. Other teachers mentioned distractions having a negative effect. These included non-math distractors such as online videos, and skill distractors, like always having a calculator or an algebraic solver at the student's fingertips. There was a group of teachers that did not see changes in proficiency as solely a result of digital resources. One response cited "attendance is waning and declining" as a second-degree effect of implementing digital resources.

One affordance reported by teachers, due to the increased integration of technology, included an increase in feedback—particularly, automatic feedback provided by online assessments. Students were given the tools to self-remediate and review mistakes nearly instantly. However, teachers noted many students do not have the study skills yet to fully capitalize on self-motivated review. One respondent stated students were "treating online math options more like video games, and that they're not really slowing down and practicing processes." While this provides a positive for one common performance metric, engagement, it must be balanced with the completion versus mastery issue other respondents raised.

Respondents said specific groups of students have shown growth in mathematical proficiency and performance. These students fell into two of main categories: students that were technologically savvy and those that were not. Students who were technologically savvy were able to exhibit growth compared to their peers. In addition, students who were high achieving prior to the pandemic and took time to self-reflect were able to continue to achieve at a high level. Furthermore, students with access to an intervention specialist or other responsible adult were able to receive the support they needed to improve their proficiency. Participating teachers also attributed this improved proficiency to the many technology pieces with interactive components. Finally, for students that were not as proficient with the technology, one teacher asserted, "[I]t has aided in leaving them behind."

COVID-19's Impact on Students' Social and Emotional Learning

School closures and the move to remote learning impacted more than just academics. According to Jones et al. (2022), "Disruptions and consequences related to the COVID-19 pandemic, including school closures, social isolation, family economic hardship, family loss or illness, and reduced access to health care, raise concerns about their effects on the mental health and well-being of youths" (p. 16). Research by Hertz et al. (2022) indicate that effective school connectedness approaches, including "classroom specific and school-wide programs, school climate change or management and disciplinary strategies, and activities within the broader community environment to promote with parent and family involvement" (p. 62) can significantly reduce the mental health challenges students experienced from virtual and combined (in-person and virtual) instruction. As such, participating teachers were asked whether they had utilized any digital resources they believed were useful in supporting the social and emotional needs of their math students.

In response to this question, one-half (25 of 50) of the participants indicated they had not used or were unaware of any digital resource that could support their math students' social and emotional needs. The majority of these responses (64%) were short one-to-two-word answers, such as "no" or "not yet," but several respondents provided longer responses, including: "SEL [social emotional learning] should be the priority of the family, not the schools" and "If I have a student with a social emotional need, I am not gonna send them to an online resource." Four participants indicated their school or district had created or found SEL activities that teachers were asked to incorporate into their lessons at least once each week. The remaining 21 participants identified resources they used to support their students' social emotional needs. Teachers' responses included:

1. "I know that students being able to message me privately in Google Classroom has been a big help. I get the notification on my phone. While most of the time it is about homework help, there were a few times that students who were struggling reached out to me. By letting them know I cared and was concerned for them really helped them feel better."

2. "[B]eing able to use Microsoft Teams and do online meetings with students and . . . parents . . . seemed to help a little bit with some of the social emotional needs of the math students, particularly if a student was at home and struggling with the math and did not want to discuss it in a group class meeting . . . so, it enabled us to do more direct intervention without having to be physically in the presence of the student."

3. "I'll just create different [Google] Forms with . . . themes . . . like 'How are you?' . . . 'How overwhelmed are you with your work' and then it'll go into stuff about like what is their home life like and not . . . negative stuff but like . . . 'What kind of careers are you interested in?'"

4. "I discovered how nice it is to just be able to message students . . . through Schoology and now that we're back in person . . . I still do that . . . it's through Schoology so it does not feel creepy, it does not feel like I'm emailing them or texting them directly or anything, it's through our school['s] . . . [learning] management system . . . and I can just quick say, 'I noticed that you had packed up at the end of class but you have not finished this assignment' or 'I see that you missed three of the same thing on the quiz, could you come in homeroom and I can help you with those?'"

Finally, teachers indicated that applications that allow for student responses to be anonymized (e.g., Desmos Classroom Activities, Nearpod) and gamification applications (e.g., Blooket, Kahoot) provided their students with opportunities to engage with the material in ways unavailable or that they had not offered during face-to-face instruction.

Comparisons of the Percent of Time Teachers Typically Spent Prior to COVID-19, and Currently Spend, Using Digital Resources When Engaging in Various Practices (e.g., Preparing Lessons, Grading or Marking Student Work)

We were also interested in addressing whether the need for lockdowns and remote teaching and learning environments had impacted teachers' use of digital resources in the long-term. Therefore, we examined potential differences in teachers' use of digital resources prior to the pandemic and teachers' current use of these same or similar resources now that schools and districts in the United States have returned to face-to-face instruction for the vast majority of the 2021-2022 academic year. As such, the survey asked teachers to estimate the broad percentage of time they typically spent, prior to covid and currently, using digital resources when engaging in the following practices: preparing lessons, preparing assessments, grading or marking student work (e.g., exam, homework), sharing ideas with colleagues, and engaging in professional development (e.g., workshop, webinar, podcast). A chi-square test of independence was performed to determine the relationship between teachers' use of digital resources to prepare lessons, currently and prior to the covid pandemic. A significant association was found, $\chi^2(5)=22.73$, $p<0.05$; that is, teachers were currently more likely to use digital resources to prepare lessons than they were prior to the covid pandemic. The distributions of teachers' use of digital resources to prepare lessons, currently and prior to the pandemic, are illustrated in **Figure 1**.

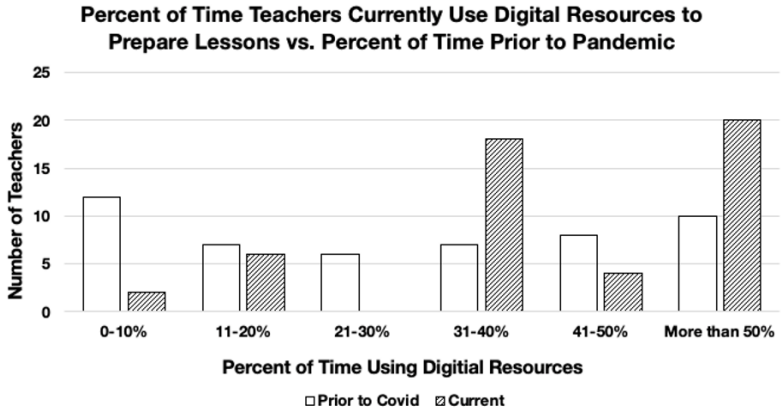

Figure 1. Percentage of time teachers use digital resources to plan lessons

Similarly, a chi-square test of independence was performed to determine the relationship between teachers' use of digital resources to grade or mark student work, currently and prior to the covid pandemic. A significant association was found, $\chi^2(5)=23.84$, $p<0.05$; that is, teachers were currently more likely to use digital resources to grade or mark student work than they were prior to the covid pandemic. The distributions of teachers' use of digital resources to grade or mark student work, currently and prior to the pandemic, are illustrated in **Figure 2**.

Finally, a Chi-square test of independence was performed to determine the relationship between teachers' use of digital resources to engage in professional development, currently and prior to the covid pandemic. A significant association was found, $\chi^2(5)=18.63$, $p<0.05$; that is, teachers were currently more likely to use digital resources to engage in professional development than they were prior to the covid pandemic. The distributions of teachers' use of digital resources to engage in professional development, currently and prior to the pandemic, are illustrated in **Figure 3**.

Although there were differences in the distributions of the percentages of time teachers typically spent, prior to covid and currently, using digital resources when preparing assessments and sharing ideas with colleagues, there was not a significant relationship between teachers' current and prior use in either of these categories.

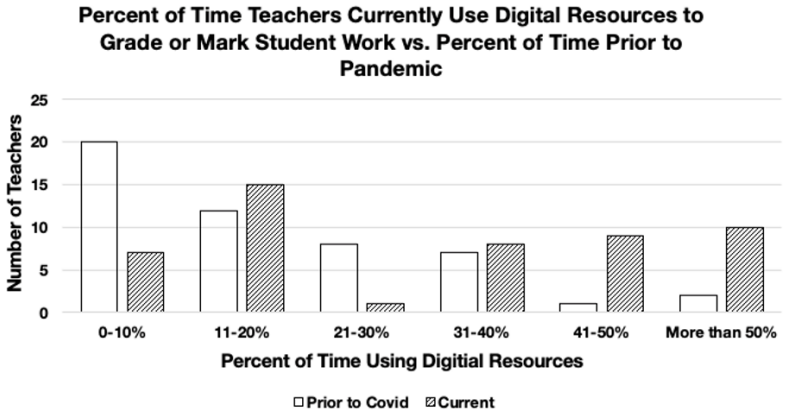

Figure 2. Percentage of time teachers use digital resources to mark or grade student work

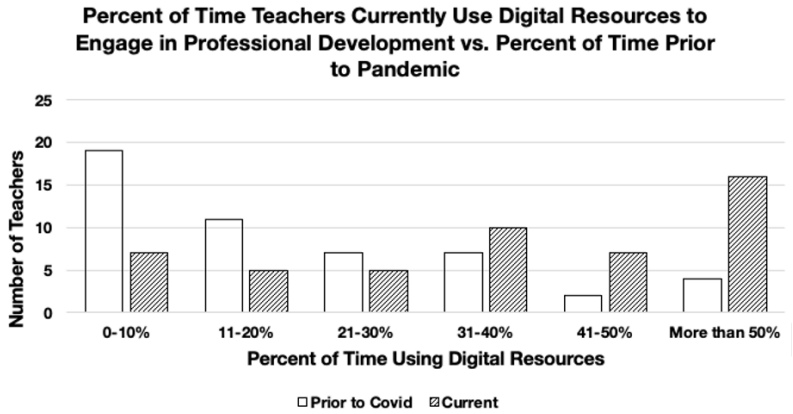

Figure 3. Percentage of time teachers use digital resources to engage in professional development

SUMMARY AND DISCUSSION

In this report, we detailed results from a survey of 50 grades 6-12 mathematics teachers and math interventions in the United States on teachers' integration of digital resources throughout the coronavirus pandemic and compared—when appropriate—our results with those of recent international research. Although teachers' and their students' experiences varied throughout the pandemic, depending on a multitude of contexts (e.g., socioeconomics, school setting), Covid-19 has "made abundantly clear how far our school systems are from being crisis-ready . . . [and the] cumulative and hierarchical nature of mathematics makes it particularly vulnerable to interruptions to study" (Foster et al., 2022, p. 1-2). Teachers moved productively to digital environments with regards to lesson planning and implementation as a result of the school lockdowns caused by the pandemic. The types of digital resources teachers used favoured technology that utilizes sharing between colleagues and other teachers around the globe. When it comes to assessment, the trade-off between features and simplicity has not tilted teachers away from traditional paper and pencil options. These traditional methods, for now, are seen as more reliable at evaluating mathematics achievement as opposed to measuring technological proficiency.

It must be emphasized that we did not ask participating teachers to video or audio-record their lesson planning sessions or their classroom instruction. In addition, we did not ask participants to submit lesson plans, assignments, or assessments. Such data would have benefited our identification of the types of resources they utilized to plan lessons, during instruction, and to create and/or administer assessments. This is a definite limitation to the study; one we would like to address through future research that includes collection and analysis of classroom video and instructional and assessment documents.

There were several additional limitations to this study, including the low teacher survey response rate, which resulted in the small sample size. Many school districts have heavy filters to prevent spam and phishing. These filters prevented many potential participants from even receiving the survey recruitment email. In

addition, the anonymity of the survey did not allow for follow-up questions from respondents. Such follow-up questions would have been helpful to gain more insight into teachers' integration of digital resources. Lastly, no students were surveyed. Therefore, the opinions and responses provided were solely those of teachers; that is, the facilitators of the learning, not the learners themselves. Future research should focus more specifically on niche areas of technology, such as digital textbooks, learning management systems, and the Google platform. Other technology-driven applications to examine include Padlet, Peardeck, and NearPod, and their uses in teaching and learning mathematics. With specific attention to mathematics, it would benefit the field to further explore the affordances and constraints that Desmos, GeoGebra, and Delta Math provide to teaching and student learning.

Teachers reported that overexposure to technology created a challenge. The sheer number of digital options teachers reported they "looked into" or "used" was characteristic of the overwhelming nature of the switch to digital. After teachers chose the tools they wished to use, they noted that students needed to be proficient in using these tools as well. Students were required to be proficient with technology, in general, and specific to each subject they took throughout the pandemic. This effect may be waning. Teachers have completed trial programs and chose effective options. Students may have used the same technology in previous classes, reducing the initial time and effort required to learn new resources. One participating teacher noted screen time is also a culprit. According to this respondent, "This year I found that a lot of our students were exhausted from staring at computer screens and really didn't want to do that." Personal accountability also seemed to be a tremendous struggle for teachers in relation to student accomplishments of tasks. Although everything was available for students online, such as notes, videos, and assignments, most students did not use their "remote" days for school. One teacher asserted, "This caused my biggest challenge of patience, and now students STILL seem to be re-learning how school every day works." Digital resources themselves came with a new set of challenges. Math teachers have commonly utilized back-of-the-book answers to create a mix of problems for students to practice. Furthermore, the answers to some of these problems can be easily checked by students. Some problems may ask students to analyse whether the answer they arrived at makes logical sense. As more students and teachers moved to problems contained in digital platforms and applications, the solutions to these problems were freely available online. Students used applications like Photomath to obtain solutions or searched the Internet for solutions.

While resources can be iterated upon and improved, the nature of a decentralized Web 3.0 creates an ever-evolving landscape of high-quality resources that provide lower and lower quality feedback for teachers. As described by one participant, "[O]ver the past two years, students became very proficient at looking up specific problems to copy the work down to turn in and submit as their own work. That was my biggest struggle." Future research should examine the detriment of such resources to students' mathematics development and ways to incorporate ideas of self-management and responsible decision-making—along with other social emotional competencies—into the math curriculum.

CONCLUSIONS

From the advent of the Covid-19 pandemic to two years on, teachers have been searching for materials and methods to support the mathematics curriculum from remote, hybrid, and technological perspectives. Many teachers found that effective integration of technology into the curriculum should anticipate student needs and optimize student learning. While educational technology has certainly transformed how we instruct our students, it does not serve as a replacement for effective teaching practices but aims to enhance the curriculum and the best pedagogical practices of the teacher. Technology is meant to support the teacher and equip them with tools to move their students' learning forward. As one progresses through the revised Bloom's Taxonomy (Anderson & Krathwohl, 2001) towards analysing, evaluating, and creating—much the same is incorporated through the substitution, augmentation, modification, and redefinition (SAMR) Model (Puentedura, 2005), a framework that categorizes four different degrees of classroom technology integration. In the SAMR Model (Puentedura, 2005), modification and redefinition are transformation steps, where a non-technological activity becomes a technological activity. The challenge is to use technology to transform a concept or task. This is what Ford (2008) referred to when she said that "curiosity can empower learners to engage in interesting and incidental learning that can positively impact students' interactions and engagement

with mathematics" (p. 29). As illustrated in the study presented here, teachers are consistently trying to find what is best for their students' mathematics development. The advent of technology-driven education began long before the pandemic. However, it has served to hasten most in-service mathematics teachers and math interventionists to evaluate their technology integration practices. The best and brightest teachers have always been searching for ways to improve and change the status quo in education. Lessons are learned, challenges are faced, and obstacles are overcome. As we move on from the pandemic, the field should focus on maintaining, exploring, and creating curricula and digital resources that will endure future crises.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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