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COVID-19 became a crisis when the World Health Organization (WHO, 2020) declared it a public health emergency of international concern on January 30, 2020, and a pandemic on March 11, 2020. To prevent infections, save lives, and minimize impact, most colleges and universities around the world canceled in-person classes and asked their faculty to swiftly move their courses online even if they felt unprepared to do so or had little to no interest in teaching online (Hechinger & Lorin, 2020; McMurtrie, 2020). The decisions on how to best carry this out varied widely. The instructional designers at the institutions of higher education, among other things, gathered, organized, and distributed resources; designed and hosted workshops to support course development; and provided technology support advocating for students and faculty alike (Xie et al., 2021).

The transition to emergency remote teaching necessitated by the COVID-19 pandemic created significant uncertainty for the nation's educators. Hodges et al. (2020) define emergency remote teaching (ERT) as "a temporary shift

of instructional delivery to an alternate delivery mode due to crisis circumstances" (n.p.). They clarify that "the primary objective in these circumstances is not to re-create a robust educational ecosystem but rather to provide temporary access to instruction and instructional supports in a manner that is quick to set up and is reliably available during an emergency or crisis" (n.p.). The authors go on to acknowledge that this quick transition to remote instruction was a contradiction to what we know about developing quality online courses. Quality online instruction takes time for thoughtful planning, and teacher educators did not have that time during the quick transition to ERT in spring 2020.

Mathematics teacher educators (MTEs), including those who had not previously taught online, were among the many faculty grappling with this abrupt migration to ERT. Using a qualitative survey research approach, this study examined MTEs' perceptions of transitioning their teaching from in-class to online, and how it impacted the quality of instruction they delivered during the COVID-19 pandemic. This shift in context (i.e., ConteXtual Knowledge (XK) in the Technological Pedagogical Content Knowledge (TPACK) framework; Mishra, 2019) from an in-person to an online learning environment required faculty to enact their TPACK unique to the online learning environment. Data were analyzed for patterns of responses to the transition so that inferences could be made about how MTEs enacted their TPACK during ERT. This work will facilitate the development of empirically informed policies and resources to aid teacher education programs in navigating the ongoing pandemic and reduce the disruption of such transitions in the future. It will also serve to illuminate the XK of TPACK that has been underrepresented in previous research (Porras-Hernandez & Salinas-Amescua, 2013). Furthermore, this work could help shape the design of professional development opportunities that promote adoption of research-based pedagogies and instructional technologies.

Our research focused specifically on spring 2020 and what issues mathematics education faculty of undergraduate and graduate students faced during that time. The research question was: What were mathematics teacher educators' experiences with migrating in-person instruction to emergency remote teaching during COVID-19?

Literature Review

In the past few years, the literature regarding emergency remote teaching has grown in scope.

Pertinent to our study, researchers have examined various topics, such as clinical practice during COVID-19 (Monroe et al., 2020; Parker et al., 2020; Pike et al., 2020), equity issues (Brewer & Cartagena, 2020; Lueders et al., 2020), synchronous learning (e.g., Flores Fahara & Lozano Castro, 2015; Goodman, 2019; Seifert, 2019), faculty challenges with teaching online (AbuZayyad-Nuseibeh, 2017), the effect of online teaching on faculty's self-efficacy in face-to-face teaching (Chiasson et al., 2015), and digital tools for improved instruction (Carey et al., 2020; Goddard, 2020; Khan & Jawaid, 2020; Oliver et al., 2020). While our research similarly targeted the teacher perspective, studies have also explored the student perspective. For example, Karalis and Raikou (2020) surveyed 103 Department of Education students in Greece and revealed that approximately 71% of students found that the shortage of personal connections among students and student/teacher bonds was a negative effect of emergency remote teaching due to COVID-19. Students also struggled with technology (55.3%) and participation issues (21.4%). Regarding positive impacts of COVID-19 emergency remote teaching, students enjoyed the ease of participating in class (65%), being able to not commute (56%), and working at home (28%).

Besides investigating the perspectives of teachers and students in online instruction, the literature indicates that there are major differences between online and in-person instruction. Teachers must develop unique pedagogies for effective and meaningful learning experiences (Kreber & Kanuka, 2006; Laat et al., 2007; Natriello, 2005). Such pedagogies include facilitating instruction, fostering discourse, encouraging social interactions, interacting with students, motivating and engaging students, fostering a sense of community, integrating technology into pedagogical inquiry, and assessing students (Baran et al., 2011; Bigatel et al., 2012; Park et al., 2013). Thus, transitioning in-person courses to online courses takes time and preparation, a key area of examination in our study.

Another area of exploration in our research was faculty's sense of preparation for online learning. Cutri and Mena (2020) examined faculty preparedness for developing or transitioning in-person courses to online formats. Using a concept matrix to synthesize key concepts in 44 sources, three concepts emerged: affective considerations, pedagogical considerations, and organizational considerations. Cutri et al. (2020) continued to study

faculty readiness and developed and validated a Faculty Readiness for Online Crisis Teaching [FROCT] scale. They identified eleven constructs within four themes associated with faculty readiness for such transitions, including: a) comfort with risk (willingness to try new things, confidence to be flexible and creative, fears and concerns, feeling in limbo), b) identity disruption (sense of self as a teacher educator, sense of self as an experienced professional), c) teaching norms (traditional teaching methods, student autonomy, emotional work), and d) equity and tenure norms (equity issues, tenure and promotion issues). Cutri et al. (2020) further grouped the constructs associated with the *comfort with risk* and *identity disruption* themes as affective factors. They describe affective factors as empathy for students as new online learners (see also Salmon, 2011) and a humbling experience for a faculty whose traditional teaching identity may feel compromised and who may experience increased stress as they venture into a new teaching modality (see also Golden, 2016; Johnson et al., 2014; Sockam & Sharma, 2008). These themes informed the construction of our survey and analysis of results.

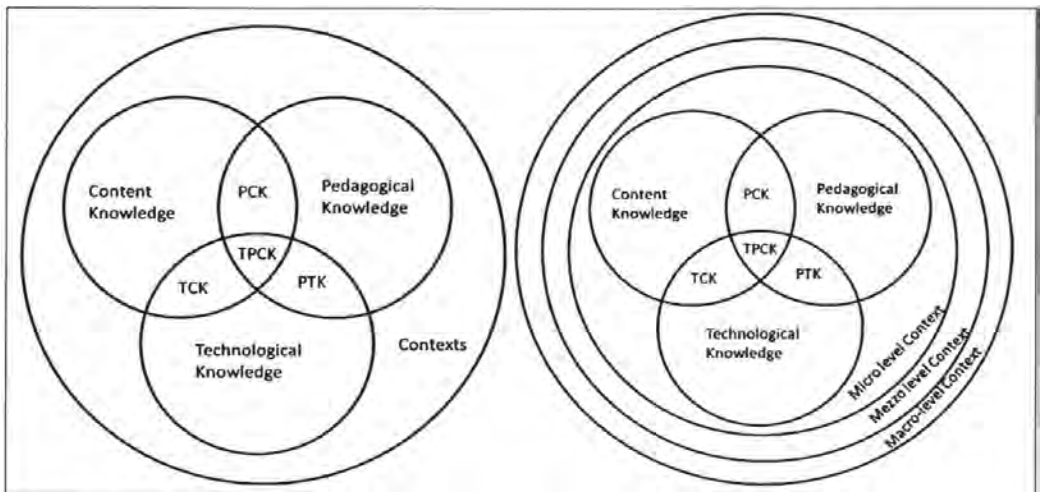
Although not specifically related to faculty readiness, Garrison et al. (2000) was at the forefront of analyzing the educational effectiveness of online learning. They identified the Community of Inquiry (CoI) as one theoretical framework that supports creating a collaborative-constructivist learning experience where learning is created in the community through the interaction of cognitive, social, and teaching presence. Cognitive presence is "the extent to which the participants in any particular configuration of a community of inquiry are able to construct meaning through sustained communication" (Garrison et al., 2000, p. 89). Social presence is participants' ability to "project their personal characteristics into the community, thereby presenting themselves to the other participants as 'real people'" (p. 89). The essence of social presence is to support cognitive presence as learners in the community share their critical thinking processes. Teaching presence supports and enhances social and cognitive presence and consists of the design and facilitation of the educational experience. Effective teaching presence guides learners' interactions and discussions while helping them construct knowledge through active discourse. The CoI framework has been adopted by many and used to create and evaluate online learning experiences (Akyol & Garrison, 2008; Arbaugh,

2008; Arbaugh et al., 2008; Boston et al., 2009; Cobb, 2011; Garrison & Akyol, 2013; Kozan & Richardson, 2014; Swan et al., 2008). This framework served as a guide when identifying themes present in our data.

The knowledge needed for teaching online includes the knowledge needed for teaching that Shulman (1986) identified as content knowledge (CK) and pedagogical knowledge (PK). Shulman believed these knowledge domains were interrelated and not mutually exclusive. For example, teachers create ways of teaching that are generic, as well as discipline-specific teaching strategies. To reflect this interrelationship, Shulman created the idea of pedagogical content knowledge (PCK). Researchers added the role of technology to the PCK framework to analyze appropriate use of technology in teaching and developed the Technological Pedagogical Content Knowledge (TPCK/TPACK) framework (Angeli & Valanides, 2005, 2009; Margerum-Leys & Marx, 2002; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001; Zhao, 2003). This framework accounts for the specialized knowledge held by teachers as they engage with technology-enhanced instruction (Niess, 2005). TPACK is a unique body of knowledge that is constructed from the interaction of its individual contributing knowledge bases: Pedagogy, Content, and Technology (Angeli & Valanides, 2009). This interaction was originally modeled by a Venn diagram of overlapping circles associated with each knowledge domain (Mishra & Koehler, 2006).

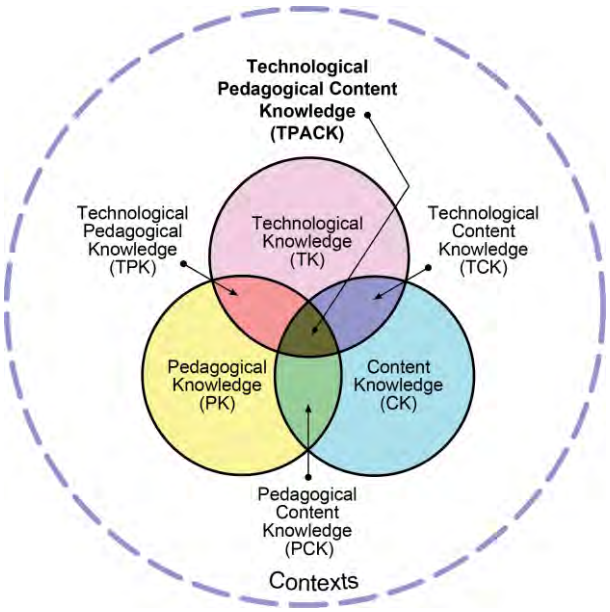
Koehler and Mishra (2008) discussed how classroom contexts vary greatly, and thus there is a wide variation in educational technology integration. Teachers and students must shift and evolve as their classroom environment changes. Koehler and Mishra included in contexts "knowledge of particular students, school social networks, parental concerns, etc." (p. 23). Porras-Hernandez and Salinas-Amescua (2013) focused on how context influences the knowledge bases and represented context as concentric circles surrounding TPACK, with micro (in-class learning conditions), mezzo (building or district conditions), and macro (societal conditions) (see Figure 1). Macro level factors are those impacting teachers and

Figure 1
Porras-Hernandez and Salinas-Amescua's (2013) micro-, mezzo-, and macro-level context



students at a more global level, such as social and political issues. The mezzo level factors pertain to local schools, such as the impact COVID had on schools' functions and policies. For the micro level, factors might include teacher or student issues at the classroom level, such as lack of access to classroom resources. Rosenberg and Koehler (2015) noted that around 36% of the literature on TPACK mentions contexts, less discusses macro-level factors (14%), and most discussions have been limited to the physical design of the classroom (micro) possibly because this is where MTEs have the most control. Mishra (2019) later changed the context in the TPACK framework to ConteXtual Knowledge (XK) (see Figure 2) to highlight that all of the knowledge domains exist in a space enclosed by the contexts of the learning.

Figure 2
Mishra's (2019) Updated TPACK Framework



The development of our survey, and subsequent analysis of our data, was grounded in the TPACK framework, with specific focus on the context of mathematics teacher education since the COVID-19 global pandemic changed the context of instruction, in most places, to be strictly online. We were interested in understanding how the context of transitioning in-person class to online during ERT interacted with MTEs' TPACK, particularly the micro-level context. For many MTEs prior to ERT, their TPACK was specifically associated with in-person instruction. Many MTEs had possibly never experienced as a student nor had formal pedagogical preparation for guiding students' learning online. Therefore, it is in this context that we focused our research which examined MTEs' perceptions of transitioning their teaching from in-class to online, and how it impacted the quality of instruction they delivered during the COVID-19 pandemic.

In conclusion, the purpose of our study was to contribute to the growing understanding of how faculty managed the abrupt transition to fully online teaching, with a sensitivity to implications for future professional development regarding integrating technology into instruction. The literature in this area is just beginning to take shape.

The FROCT, CoI, and TPACK frameworks served to inform our coding process of faculty responses to the survey and subsequent analysis of results.

Methods

This qualitative study (Creswell, 2013) examines patterns to more fully understand MTEs' personal experiences with their transition from in-person to online classes during ERT due to COVID-19. The *Mathematics Teacher Educators' Migration to Online Teaching in Response to COVID-19* survey was designed specifically for this study based on previous research (Baran et al., 2011; Bigatel et al., 2012; Lederman, 2019; Mishra & Koehler, 2006; Niess, 2005; Park et al., 2013; Porras-Hernandez & Salinas-Amescua, 2013) to gather data about MTEs' mathematics education or mathematics content classes that support a teacher education program for undergraduate and/or graduate students.

Participants

The target population of this survey was members of the Association of Mathematics Teacher Educators (AMTE). The role of AMTE, as the "largest professional organization devoted to the improvement of mathematics teacher education" (https://amte.net/about), made their membership a valuable population to access. The target population of this study was a convenience sample of approximately 943 AMTE members. We asked AMTE for information about its members, and the only information that was shared was that the members, at the time the survey was released, consisted of 210 assistant professors, 221 associate professor, 158 professors, 148 graduate students, 47 K-12 teachers, 28 lecturers, 22 retired faculty, 19 instructors, 18 researchers, 10 deans, nine adjunct faculty, eight postdoctoral positions, four consultants, two Chief Executive Officers, two directors, one provost, and 36 other members with various titles not specific to one previously identified.

The sample includes 218 anonymous respondents, of which nine were discarded due to their lack of teaching mathematics and/or mathematics education classes during the spring 2020 semester. Of N = 209 MTE participants, 169 (80.9%) completed the entire survey, spending on average 34 minutes completing the survey. These participants included 122 females, 42 males, one transgender, and four preferred not to answer (see Table 1). The age of the participants was between 20 and 30 years old (n = 1), 31 to 40 (n = 51),

41 to 50 (*n* = 47), 51 to 60 (*n* = 43), 61 to 70 (*n* = 18), and 71 to 80 (*n* = 3), with six preferring not to answer. Participants estimated the percentage of their position devoted to teaching as 1%–25% (*n* = 13), 26%–50% (*n* = 48), 51%–75% (*n* = 49), or 76%–100% (*n* = 58), and one did not answer the question.

Table 1
Participants' Rank, Gender, and Career Status

Rank	Gender	Career status					Total
		Early career	Mid career	Late career	Retired	Prefer not to answer	
Assistant Professor	Female	27	6	3			36
	Male	9		1			10
	Transgender	1					1
	Prefer not to answer	1				1	2
Associate Professor	Female	1	24	8		1	34
	Male	1	6	4			11
	Prefer not to answer		2				2
Professor	Female		6	16	2		24
	Male		5	4	1	2	12
Visiting Professor	Female		1				1
Lecturer	Female	7	4	3			14
	Male	3	1	1			5
Adjunct	Female			1			1
Graduate Student	Female	6	1				7
	Male	1				1	2
Retired	Female				1		1
Prefer not to answer	Female		3	1			4
	Male		2				2
Total		57	61	42	4	5	

Participants mostly reported teaching only undergraduate classes (*n* = 154), though some taught only graduate classes (*n* = 17), a combination of undergraduate and graduate classes (*n* = 37), or other (*n* = 1). Similarly, most taught in a semester system (*n* = 188), though some taught on the quarter system (*n* = 19), and two taught in some

"other" system. Due to the timing of the transition, MTEs teaching on a semester schedule transitioned to COVID-19 instruction in the middle of a term, while those on the quarter schedule transitioned during spring break.

Measures

The *Mathematics Teacher Educators' Migration to Online Teaching in Response to COVID-19* survey was administered online (Nesbary, 2000), and participants could access it through a link sent to them via email. The intended use of the survey was to gather a qualitative snapshot of MTE's beliefs and experiences surrounding the (hopefully) rare context of migrating in-person instruction to ERT during a global pandemic. A survey was the preferred method of data collection because it permitted a time-sensitive method for collecting data, as it was deemed imperative to collect MTEs' perceptions soon after they experienced the transition to emergency remote teaching. A survey was advantageous also because it was a method for identifying perceptions of MTEs from a subset of the entire population of MTEs.

The survey (please contact the authors to obtain a copy of the survey) has 25 items: 15 short answer, six free response, and four Likert scale questions. Summary items addressed demographic information (e.g., gender, age, rank, and career status), teaching context (e.g., academic levels, term system, modes of instruction), and pandemic teaching transitions (e.g., courses moved from in-person to online, number of working days given to transition classes to online). To assess experiences migrating in-person instruction to ERT, questions were asked about how MTEs changed or created pedagogy (Baran et al., 2011; Bigatel et al., 2012; Park et al., 2013) for facilitating instruction, generated opportunities for students to teach and to learn from their own teaching and the teaching of others, engaging students, fostering a sense of community, meeting diverse learning needs, assessing students, and integrating technology into pedagogical inquiry.

Nine educators were solicited to establish the instrument's content validity because of their level of expertise in higher education, at least 15 years of research experience, and their publication records in areas of mathematics education, preservice education, technology education, and survey research. Four outside MTEs and one instructional technology expert reviewed the survey instrument to confirm that the survey questions would gather the data intended to answer the research question.

Survey questions were revised or deleted based on their feedback, and the MTEs verified the changes. The survey was then piloted a second time with three new MTEs and one survey construction expert. Suggested revisions were incorporated, and the MTEs verified the changes. Since minor changes were made to the survey, the authors sent the survey to the AMTE members at the end of May 2020.

Analysis of closed-ended responses (e.g., multiple choice, Likert-type) was limited to simple descriptive summaries of each individual item. Analysis of open-ended responses included multiple layers of analysis consistent with a modified version of the Qualitative Hypothesis-Generating process outlined by Auerbach and Silverstein (2003). In their work, the authors describe a way of analyzing data that begins with identifying relevant text that is defined as "passages of your transcript that express a distinct idea related to your research ideas" (p. 46). The next step in the process involves organizing this text into repeating ideas, or ideas that appear in the text from two or more sources. Third, these repeating ideas are combined into themes, and then the research builds a theoretical construct from the themes (Auerbach & Silverstein, 2003).

Thus, using the coding processes described above, the four authors took the MTE participants' open-ended responses and identified relevant text. For example, Participant 8 shared:

> The elementary preservice content class usually has a short "lecture" then activities in which they present the answers and discuss the answers in a whole class setting. Online I changed to them reading the textbook and responding to the activity questions for both sessions. The class meeting online was more of a community building time. I changed the final (not comprehensive) for the secondary to more multiple choice - fewer discussion questions. I entered in my final that I had changed to multiple choice (comprehensive) in a previous semester and put it online.

In this passage, one author identified three pieces of text that seemed relevant to our research question:

- Online I changed to them reading the textbook and responding to the activity questions for both sessions.
- The class meeting online was more of a community building time.
- I changed the final (not comprehensive) for the secondary to more multiple choice - fewer discussion

> questions. I entered in my final that I had changed to multiple choice (comprehensive) in a previous semester and put it online.

A second author confirmed that this text was relevant. If a discrepancy arose between these two authors, the text was highlighted and discussed in a meeting among all four authors. Justifications of coding were considered with final coding reaching 100% consensus.

Next, two of the authors organized the relevant text into repeating ideas. To illustrate, the first piece of relevant text listed above describes a way the participant changed their pedagogy. Since other participants noted in some responses that they changed their pedagogy due to ERT, the repeating idea of *Changing pedagogy to account for online context* was created for all such relevant text. All four authors convened to discuss the repeating ideas until 100% consensus was reached.

Finally, two of the authors combined the repeating ideas into themes. The idea of *Changing pedagogy to account for online context* was related to nine other repeating ideas including: *Assessment of students online* and *Changing/Adding content to the class*. As a group, these three and seven other repeating ideas were all related to **Instruction** and were labeled as representing that theme. Again, all four authors convened to discuss the themes until 100% consensus was reached.

Ethical Considerations

Participants were informed that all information that they provided would be confidential, no identifying information would be collected, and only the researchers would have access to the responses. The survey is in compliance with the first author's Institutional Review Board policy for the protection of human subjects in research.

Survey Results

Since the survey included various components, the results will be discussed to address: a) MTEs' teaching experience at the time of ERT, and b) how and reasons why MTEs changed or created pedagogy for facilitating instruction.

MTEs' Teaching Experience at the Time of ERT

Data collected on MTEs' teaching experience discussed in this article included number of online or hybrid courses taught before ERT; number of working days given to transition classes to online; responsibilities for teaching in-person, asynchronous, synchronous,

and blended courses before and after the onset of the COVID-19 pandemic; and types of students (e.g., undergraduate, graduate). Based on the sample (*N* = 209), many MTEs had limited prior experience teaching online or hybrid courses (0 classes = 30%, 1 to 5 classes = 31%, 6 to 10 classes = 10%, 11 or more classes = 9%, did not respond = 20%) before the transition to ERT. Moreover, MTEs reported an average of just M = 6.4 days (Mdn = 5) to carry out the transition to ERT from notification of the change to the first day they were expected to teach. Most (58%) had five days or fewer to carry out the transition (six to ten days = 31%), migrating a median of two in-person classes to an online format (none = 4%, one = 25%, two = 38%, three = 20%, four or more = 13%). MTEs' responsibilities for teaching in-person, asynchronous, synchronous, and blended courses before and after the start of the COVID-19 pandemic are summarized in Table 2. Prior to COVID-19, most MTEs (70%) only taught in-person classes, with nearly all teaching no synchronous (94%) online courses and many teaching no asynchronous classes (79%). After the transition to ERT, no MTEs (0%) taught in-person classes, many (68%) taught at least some asynchronous online courses, and many (68%) taught at least some synchronous online course. At the time of the transition, 154 MTEs were teaching only undergraduate courses, 17 were teaching only graduate level courses, 37 were teaching a combination of undergraduate and graduate level

Table 2
Relative Distributions of MTE Teaching Modalities Prior to and after COVID-19 Transition

Teaching modality	Percentage of teaching modality prior to COVID-19				Percentage of teaching modality after transitioning to online instruction			
	0%	1-49%	50-99%	100%	0%	1-49%	50-99%	100%
In-person	2%	2%	25%	70%	100%	0%	0%	0%
Asynchronous	79%	16%	4%	1%	32%	17%	28%	23%
Synchronous	94%	5%	1%	0%	32%	15%	30%	23%
Blended	91%	9%	0%	0%	89%	5%	2%	4%

courses, and one responded teaching "other".

MTEs' Changed or Created Pedagogy for Facilitating Instruction

Table 3 summarizes MTEs' reports of how the transition to ERT caused them to change aspects of their pedagogy (0 = *Not at all* to 4 = *Completely*) and whether the change was positive, neutral, or negative. The types of changes are listed in Table 3 in descending order by the extent of reported changes, with the largest reported change being "*opportunities for students to teach and to learn from their own teaching and the teaching of others"*, with most (56%) describing the effect of the change as negative. Similarly, the second largest reported change was *how students were engaged in learning*, with many describing the change as negative (37%) or neutral (37%). Two types of changes were more frequently reported as positive rather than negative: *use of general technology tools for students' learning* (36% positive vs 4% negative) and *use of mathematical technology tools for students' learning* (37% positive vs 18% negative).

MTEs were asked to share some examples to gain a deeper understanding of their responses. These qualitative responses were used to triangulate and provide context to the quantitative responses. Most of the comments about what aspects changed with opportunities for students to teach and to learn from their own teaching and the teaching of others were about preservice teachers losing their student teaching experience, such as:

> My students' practicum experience was cut short, and they could no longer go into the schools. We had them complete a final reflection and that was it. It felt like the teaching experience was cheapen for them. (Participant #55)

> I was also in the midst of supervising student teachers in schools - which was completely halted. These students completed their learning through writing lesson plans but missed out completely on the in-person learning from and about their own teaching. (Participant #75)

Table 3
Percentage Distributions of Changes to MTEs' Instruction due to COVID-19

Type of Change	Extent of Change†						Effect of change*			
	0	1	2	3	4	NA	Pos	Neu	Neg	NA
Opportunities for students to teach and to learn from their own teaching and the teaching of others	7	10	19	34	29	1	10	18	56	16
How students were engaged in learning	2	18	22	45	13	0	11	37	37	14
Assignments/ tasks / formative assessments of the course	4	21	23	40	11	1	17	35	33	14
Use of general technology tools for students' learning	6	16	26	39	11	1	36	43	4	17
Created or maintained a community among students	3	18	31	30	17	0	17	34	34	15
Summative assessments of students' learning	9	21	25	26	17	1	14	47	24	16
How taught mathematics content	5	26	33	25	10	2	12	43	31	14
Instruction to meet diverse learner needs and ensure equitable access to content in your class	10	24	30	29	7	1	14	36	34	16
Use of mathematical technology tools for students' learning	18	19	22	29	10	1	37	37	8	18

Note: Percentages may not sum to 100 due to rounding; NA = no response.
† Extent of Change scale: 0 = Not at all, 1 = Somewhat, 2 = Moderately, 3 = A lot, 4 = Completely
*Effect of Change scale: Pos = Positive, Neu = Neutral, Neg = Negative

Other comments about what aspects changed were about class projects:

My planned final project included student groups presenting an interactive

> mathematics activity during the final exam (using a lesson from the Bridges in Mathematics series). I abandoned this project with the switch to remote learning, as the primary goal of this assignment was to get my students comfortable in front of other people and to get them to try facilitating an interactive activity with "students" in the classroom. (Participant #108)
>
> Normally students teach a community math lesson with a group of students in an after-school program, but I had to modify the assignment significantly. So, students weren't able to reflect on their lesson implementations. (Participant #4)

Other negative comments were mainly about how MTEs engaged students in learning. Two different participants responded:

> I found that online everything was more difficult - not easy to engage students - not easy to teach advanced math without seeing people - not easy to assess understanding. (Participant #144)
>
> I generally have students work on classwork during class time in groups. I then walk around the room and ask questions and guide students' thinking. I chose to not require attendance, and groupwork generally did not go well. I tried to replicate some of what I do through videos, but I know that many students did not even watch the videos. As a result, my students' classwork, which I collect and grade (mostly for completeness), and which is usually good (as we go over a lot of it during class), was generally not good. It took hours to grade and try to give feedback that would help students make connections. (Participant #167)

Although most of the instructional strategies that MTEs changed were negative, there were two aspects that received more positive responses than negative responses. They were *the use of general technology tools for students' learning* and *the use of mathematical technology tools for students' learning*. An example of each follows:

> Sharing students' work on Google slides during synchronous instruction helped more students see each other's thinking even more than would have happened during class. (Participant #25)
>
> Math technology tools - we did a 'pop up' session with TI84s and rovers with 3 of us attending (6 ft. apart!) and others watching on zoom and inviting another teacher who uses them in her math classroom to join us on

> zoom to talk about her experiences (I wouldn't have thought of this if we were just doing this in our weekly on campus class). (Participant #26)

Themes in How MTEs Changed or Created Pedagogy for Facilitating Instruction

Analysis of the six open-ended responses identified relevant text that were used to create repeating ideas in which five themes emerged: **Instruction**, **Tools**, **Affective Experiences**, **Outside Influences**, and **Learner Development**. Of these, **Instruction** and **Tools** were the most common themes.

Instruction. Participants (*n* = 134, ~64%) shared the most ideas around Instruction as shown in Table 4. *Changing pedagogy to account for online context* was the most common repeating idea expressed related to Instruction. This is evidence that the micro-level context factor (Porras-Hernandez & Salinas-Amescua, 2013) required MTEs to enact their TPACK to help them shift their TPACK from an in-person to an online learning environment as they adapted their pedagogy for online instruction.

Table 4
Repeating Ideas for Instruction Theme

Repeating idea	Frequency
Changing pedagogy to account for online context	139
Negative evaluation of online teaching quality	127
Assessment of students online	84
Instructional changes that persist after emergency remote learning	57
Changing/Adding content to the class	37
Positive evaluation of online teaching quality	32
Concern about outside help	22
Feeling unprepared to teach online	19
Both positive and negative evaluation of online teaching quality	18
Preparation for future online teaching	15
Total	550

MTEs often spoke of *Changing pedagogy* and *Negative evaluation of online teaching quality* together. For example, Participant 50 shared:

> Because students did not have access to the hands-on materials typically a part of my classes, I connected them with the MLC [Math Learning Center] virtual

> apps and engaged them more deeply in using the Google Suite of tools for collaboration. Due to COVID-19 and the fact that I was teaching practicing teachers, I gave them huge leeway when they submitted their work, knowing that they were under a lot of pressure. This negatively impacted their learning, their ability to participate fully in class discussion, my ability to determine the broad range of needs (because there was a gap in who I was hearing from) and I am STILL trying to unbury myself from all the incomplete and make-up work.

MTE also used their TPACK to change in-person assessments to *Assessment of students online* during this difficult time:

> I used breakout rooms in Zoom w/Google slides that students could comment/draw on to facilitate conversation. I found it made students accountable in a new way. I also used PollEve to get their thoughts during instruction. The instant feedback was useful to support what I covered. I was unable to really differentiate much because it was hard to tell where students were with their work. I did help after class w/private Zoom sessions but it's not as effective as seeing and hearing them discuss content. Support would be easier if I could observe it more readily. (Participant #146)

This MTE taught 85% of their instruction in-person and 15% asynchronously prior to ERT and 80% synchronously and 20% asynchronously during ERT. Although this MTE expressed a disadvantage with meeting via Zoom versus meeting in-person, their comment suggests that enacting their TPACK to use Google slides helped with student accountability and using Poll Everywhere helped with receiving instant feedback during synchronous instruction. This shift in context to teaching synchronously and using Zoom breakout rooms with Google slides "made students accountable in a new way", which is evidence that their knowledge about teaching synchronously evolved (XK) as they shifted instructional contexts during ERT.

MTEs also commented about some adjustments they felt could last, namely the repeating idea of *Instructional changes that persist after emergency remote learning* and the repeating idea of the *Positive evaluation of online teaching quality*. Participant 167 shared such a view:

> I believe that in math classes for teachers, it is important to have synchronous components that allow for group work. I am aiming to have targeted

> assignments for students to do during the synchronous class times and make use of computer designed assessments, so that students know if they are on the right track before they hand in work to me (perhaps a week later). I want to continue to make use of virtual manipulatives, even when I am back teaching in person, as I found these beneficial and my students could access these outside of class.

This MTE had shared on a different question that 100% of their teaching contract was in-person prior to ERT. The transition to the online learning environment (XK) was contributing to the development of this MTEs' TPACK as they learned synchronous instruction, created new assignments and assessments, and began using virtual manipulatives.

Another positive modification, which was coded as both *Positive evaluation of online teaching quality* and the idea of *Changing/Adding content to the class*, was Participant 98's remark when discussing a new project:

> I did turn a teaching project for the course into an open-ended content integration experience project. While the opportunity to teach and learn from teaching was lost, the projects were very rewarding and, in some ways, connected to current events.

Although this MTE had some online teaching experience prior to ERT with 60% in-person and 40% asynchronous, they changed to 60% asynchronous and 40% synchronous during ERT. To adjust from the context of in-person to synchronous classes (XK), they changed a course project, and this "rewarding" experience is evidence that this MTE's TPACK was positively influenced.

Not all MTEs had polarizing opinions about online teaching. Eighteen comments spoke about the pros and cons of this new teaching environment—namely, the repeating idea of *Both positive and negative evaluation of online teaching quality* that a pandemic created, such as the feelings of Participant 107 about group discussions:

> One outcome I am particularly thankful for is the student voice. Once we were online it was clear that when students were sharing they had the attention of all the others completely. I felt that although it was more of a challenge to have student discussions as a whole class, it was easier to make sure students had a turn and that all the others heard what was being said. This accountability allowed for students to support each other and they would often ask for more time in their small

> groups to make sure they were comfortable with what they would report out for their team.

This participant had taught 100% in-person prior to ERT and had pivoted to teaching 100% synchronously. Their remark is evidence that the synchronous learning environment or new micro-level context contributed to the development of their TPACK as they expressed that student accountability was easier in the synchronous environment.

These data indicate that the rapid transition to ERT had a consequential impact on MTE's **Instruction**. This theme was mentioned 550 times in the data, more than any other theme. Prior to ERT, it was possible to be an MTE and incorporate very little technology into instruction. This experience of changing so many methods of instruction to accommodate for online instruction—almost overnight—was clearly the most influential experience for MTEs from this time.

Tools. The next most common theme to emerge from the data was Tools. Table 5 lists the frequency of the repeating ideas expressed under this theme among 134 participants (~64%). When we asked in Question 16, "What challenges or affordances to providing equitable practices did you experience during the migration to online teaching?", *Technology issues* were apparent. Participant 30 shared:

> I think the biggest challenge is the inequitable internet capability in the rural areas of our state was one of the biggest issues. Students were challenged with having to travel to the nearest town to connect or they would have to hot-spot their phone. This limited their ability to watch/record etc. I am sure there are other inequities, but this was my biggest challenge.

This MTE was teaching 100% in-person prior to and 100%

Table 5
Repeating Ideas for Tools Theme

Repeating idea	Frequency
Technology issues	107
Course format (asynchronous versus synchronous)	92
Virtual meeting tools	80
Video tools for delivery	75
Digital tools for instruction	60
Digital manipulatives	58
Physical manipulatives	28
Total	500

synchronously during ERT. This new synchronous context posed challenges for some of their students, which highlighted for this MTE the digital divide in their state.

Another challenge for some was the *Course format*. Participant 106 shared:

> This spring I taught three sections of an undergraduate math methods course. I typically would do a lot of lab-based instruction using manipulatives and cooperative/IBL learning in the classroom. Shifting to remote teaching and learning meant using Zoom break out rooms and virtual tools/apps to mimic the activities we would have completed face to face. There were challenges with technology, screentime burnout (moving ALL courses to online courses simultaneously was a lot for students to handle), and mental health/anxiety issues to adjust to with the shift to all coursework happening on a computer.

This MTE was not alone with noticing "screentime burnout" and "mental health/anxiety issues" during a time when all courses simultaneously shifted to online–a heavy load for many students.

Some participants were able to cite affordances from their experiences, including how *Virtual meeting tools* and *Video tools for delivery* facilitated opportunities for learning in this new environment. Participant 169 described:

> I can see where short (5-minute) videos created by me could be added to the course and they would be helpful for students to use along with any in-class instruction. Same thing with using conferencing software to hold virtual office hours. Also, using something like Flipgrid with students to post short video presentations would add an interesting aspect to the course for preservice teachers—especially now that some school districts ask applicants to create Flipgrid videos as part of the interview process.

This participant had taught 100% in-person prior to ERT and pivoted to 100% asynchronous instruction. This new context of instruction (XK) helped to further develop their TPACK since they created short instructional videos, used Flipgrid (now called Flip), and held virtual office hours.

Anyone who teaches with technology knows there will always be affordances and constraints of technology tools. The repeating ideas of the MTEs detailed how much **Tools** impacted their experiences during ERT. While MTEs noted new learning experiences with technology tools (*Virtual meeting tools*; *Digital*

manipulatives), they also noted challenges (*Technology issues*). In all, MTEs shared 500 unique ideas describing their experiences with this theme.

Affective Experience.

Affective Experience was the third most common theme, but it contained the most oft-cited repeating idea: *Student engagement*. Table 6 details the frequency of the repeating ideas expressed in this theme among 115 participants (~55%).

Table 6

Repeating Ideas for Affective Experience Theme

Repeating idea	Frequency
Student engagement	173
Sense of community	58
Empathy	35
Encouraging reluctant learners	10
Total	276

Keeping students engaged was clearly on the minds of the MTE participants. MTEs went to extraordinary lengths to improve *Student engagement*. For example, Participant 13 shared their experiences with this work:

> Student engagement in the content was my biggest challenge as it was a math content course. I learned how to utilize Google Slides and Jamboard as ways for students to collaborate during class and continue to build a mathematical community. This was a positive because I will use some of these tools when back to f2f. The challenge was that students were ill equipped with technology tools and had to learn too—this slowed us way down. Also, finding simple manipulatives online was time consuming and sometimes they got in the way of learning the larger concepts because we were learning how to utilize these tools. We also had a harder time communicating with each other. We utilized break out rooms and chat features but it fell far from the kinds of interactions we have in the classroom together. It was hard to keep student excitement and energy up each class. It wasn't for a lack of trying on anyone's part though. Students stepped up and did their best.

Although this MTE tried to communicate with their students, enthusiasm for learning was not the same even though both the MTE

and students rose to the challenge. This MTE's response is evidence that they needed to further develop their TPACK related to communicating while online (XK). However, this MTE's use of new tools to encourage student engagement, including Google Slides and Jamboard, was evidence that they enacted their TPACK to create instructional opportunities for students. It appears that they continued to enact their TPACK as they planned to use these tools in their face-to-face class the subsequent semester.

For some MTEs, creating a *Sense of community* in the online classroom was a challenge. Participant 161 shared:

> Despite being digital natives, this was extremely challenging for my students. All the human interaction that goes on in a classroom, even small details, turned out to be very important. Facial expressions, reactions, sharing of feelings and ideas were all missing online. There did not seem to be any kind of personal connection, and efforts to do so felt forced and fake (in the words of my students). At the same time, administrators at my institution eyed online activities in a different way. Without acknowledging the loss of many face-to-face benefits, they wonder if we could not save money by doing all or partial online instruction all the time going forward.

This MTE transitioned from 100% in-person instruction to about 95% asynchronous and 5% synchronous instruction. Their response indicates that they needed to further develop their TPACK in this new context of asynchronous instruction (XK) to help them create community among their students. In contrast, one particular MTE (Participant 6) was puzzled about how the pandemic helped to transform their class from one that was struggling to create community to a class filled with a community of learners. They shared:

> I have experience teaching online and had developed a rapport with my face-to-face class, so moving online abruptly was not terrible for our course content. More difficult was adjusting to meet their different needs and supporting them in their different circumstances. For my course that had been 100% online prior to the abrupt change across our PK–16 system, I had been struggling with creating community. This move really helped us—they saw I cared about them, and they realized they had a community of learners to continue to grow with. I don't know why it took such drastic circumstances for us to "get there." That is what I am trying to figure out so we "get

> there" sooner next time. I was working so hard on trying to build the community but didn't feel as if it was coming together until that happened in March.

It is possible that this MTE's empathy toward the students who faced many challenges helped create a community among the class. Other ways MTEs showed *Empathy* toward their students was by not using videos and timed assessments since some students had limited access to high-speed Internet. Participant 63 explained: "A few of my students did not have access to high-speed internet when they were home. I did not use videos much since that challenged these students. I also did not do time assessments for the same reason."

This theme showed the compassion that MTEs had for their students' experiences as learners during ERT. The transition was not just about the MTEs and their own challenges; their students were a major concern. MTEs wanted their students to feel like they belonged and were important to the class. MTEs also wanted their students to be engaged with learning, and this idea repeated more than any other in the data (*n* = 173). The theme of **Affective Experience**, present in 276 repeating ideas, shows the different ways MTEs worked to address these concerns.

Outside Influences.

Throughout the qualitative data, MTEs conveyed various ideas in the **Outside Influences** theme. Overall, ideas around *Personal issues* were the most common response in this question. Table 7 displays the frequency of this and the other repeating ideas in this theme among 70 participants (~34%).

Table 7

Repeating Ideas for Outside Influences Theme

Repeating idea	Frequency
Personal issues	56
Student needs	32
Time constraints	28
Total	116

Participants shared thoughts that indicated the complexity of the *Personal issue*s impacting students and their abilities to learn during ERT. Some issues were related to financial impacts and needing to support siblings:

> Lack of access to internet, devices. Lack of time—some students had to essentially take

> on homeschooling for siblings while others were bored being stuck at home. Students from low socioeconomic backgrounds or whose parents were suddenly out of work had to take on more hours at their job, preventing them from coming to synchronous classes. (Participant 78)

MTEs also saw the impact of issues around the safety of the students' families as well:

> The biggest things were not about online vs. in person so much as other inequities that were always there but became more visible and more pressing, such as some students still having to report to work and feeling very worried about exposing themselves or immune-compromised family members to the virus while others could stay home and/or know that if they or their family members got sick, they would have the medical care they needed. (Participant 19)

In addition to *Personal issues*, MTEs expressed concern about *Student needs* that included equity matters when trying to provide adequate instruction for students:

> Fall online instruction will be a challenge as I think more about how to do mathematics assessments well and maintain validity and reliability. However, for students with different learning needs, such as non-native English speakers, people who are hearing or vision impaired, or documented differences with ADA, face-to-face is, in my opinion, the only way to teach fairly and equitably. A significant number of my students have children and jobs, and so to have them at home all the time as well meant I could not expect to hold a "normal" class time. Finally, many of my students did not possess required equipment for online instruction, such as a microphone, webcam, and Microsoft Office. (Participant 161)

Lastly, *Time constraint*s was an additional repeating idea in Outside Influences that concerned MTEs. The impact of this repeating idea could be found in the MTEs' abilities to balance the demands of grading and planning in this new online environment:

> One major thing I reflected on during the experience was just how much of my teaching approach relied on getting information (both verbal and non-verbal) from students on how things were going. It's near impossible to "adjust in the moment" when you're making plans a week before students see them and seeing the results

> of that "instruction" a week later. I also found myself spending way more time planning and grading during the online migration than I would have if the classes had been held in person. Some of the increased grading was because I couldn't listen in on students' thinking in class. (Participant 158)

In contrast to the previous theme of **Affective Experiences** where the MTEs showed compassion for their students as learners, the **Outside Influences** theme showed the compassion that MTEs had for their students' experiences as human beings during ERT. MTEs recognized that there were many factors at play in the personal lives of their students, and this influenced students' ability to engage with the class. MTEs shared 126 ideas related to this theme.

Learner Development. The final theme, **Learner Development**, had the fewest and only two repeating ideas: *Mathematics understanding* (*n* = 63) and *Students develop digital skills* (*n* = 23) shared among 86 participants (~41%). In one question that asked MTEs to "share some examples of how and why the mathematics changed due to the online environment—if applicable", ideas around Learner Development were most frequent. MTEs expressed ideas about the level of *Mathematics understanding* that was developed in their classes. When adjustments were made to the content and the pedagogy in the course, some saw value added. For example, Participant 160 shared:

> Usually, for the probability lesson, I have them design a simulation for an event with blocks in a bag and then carry out the simulation. It takes a lot of time, and the hardest part for them typically was designing a simulation that matched the real-world event. With the online tools, Shodor's marble bags and CPM's marble bag, and making histograms/dot plots in Google Doc tables, they noticed the sampling distribution much better—they saw the variation and they saw the center and explained pretty well. With the hands-on simulations, there was just so much logistically that they lost sight of the mathematics, I think.

This MTE was 100% in-person prior to and 100% synchronous during ERT. This MTE enacted their TPACK as they shifted from the in-person to synchronous context and discovered that using an online tool versus blocks in a bag was a valuable learning experience for their students.

The second repeating idea in the Learner Development theme was *Students develop digital skills*. This transition to ERT sparked, for some

MTEs, the need for teacher preparation programs to prepare preservice teachers for online instruction. Participant 76, who was teaching 100% in-person prior to and 100% synchronously during ERT, shared:

> I realized the importance of non-verbal feedback. In addition, I believe that we need to prepare pre-service teachers for teaching 100% digitally. There are so many options teachers have in terms of quick formative assessment data, virtual manipulatives, and exposure to digital literacy. Students who were in a digital classroom had little to no transition to eLearning.

Their response is evidence that the shift in context from in-person to synchronous influenced this MTE to use formative assessment data, virtual manipulatives, and digital literacy, all which is evidence of TPACK development.

MTEs wanted their students to be prepared for teaching mathematics, and they recognized the ways that ERT influenced their students' mathematics content knowledge and knowledge of technology. **Learner development** had the fewest repeating ideas in the data (n = 86). However, this theme was very important since it represents students' knowledge of mathematics and tools, which are both essential knowledge for teaching in the digital age.

Discussion

Since some students who were learning in-person prior to ERT have not yet returned to in-person classes, it does not appear that instruction at all levels, K–12 and higher education, will go completely back to the pre-COVID-19 pandemic normal anytime soon. The course format context—face-to-face, hybrid, asynchronous, synchronous, etc.—was strongly influenced by the COVID-19 pandemic. As discussed in the results section, the shift to ERT influenced **Instruction**, **Tools**, **Affective Experience**, **Outside Influences**, and **Learner Development**. Furthermore, the shift of context to ERT influenced MTEs to enact their TPACK. As educators all over the world quickly transitioned into learning without classrooms, previous understandings of the micro-level context (Porras-Hernandez & Salinas-Amescua, 2013) that for many MTEs—70% in this survey— focused only on the physical classroom space they were now lacking. Contrary to what research purports about effective and meaningful online learning experiences (Kreber & Kanuka, 2006; Laat et al., 2007; Natriello, 2005), many of the MTEs' readiness to transition to online teaching (Cutri & Mena, 2020) was lacking.

Macro-level factors (Porras-Hernandez & Salinas-Amescua, 2013), like COVID-19, heightened their awareness of micro-level conditions represented by teaching online. Many MTEs enacted their TPACK and shifted and evolved their TPACK unique to the online learning environment (Baran et al., 2011; Bigatel et al., 2012; Borup & Evmenova, 2019; Park et al., 2013). They relied on their TPACK to rethink, revise, and adapt their instructional strategies for engaging students, fostering a sense of community, facilitating discourse, assessing students, and integrating technology into pedagogical inquiry, just to name a few. For some MTEs, this required them to teach class synchronously while creating new pedagogical ways to engage students in discussion through breakout rooms, discussion boards, Google Docs, Google Slides, and/or Google Jamboards. Whether the context was synchronous or asynchronous, some changed their pedagogy for assessments and created new assignments and formative and summative assessments to gauge student learning. They created videos and learned to use different or sometimes new technologies such as Desmos, CODAP, Flipgrid (now Flip), and virtual manipulatives for instructional inquiry.

Teacher preparation programs in every nation must acknowledge and address the changes to the micro contexts that influence TPACK. If faculty are expected to move forward with this change, they need high-quality, targeted professional development. The themes from our survey data indicate that this professional development should focus on knowledge and skill building with **Instruction**, **Tools**, and **Learner Development** specific to remote teaching. Our survey results suggest topics to include in teacher education programs: student engagement, changing pedagogy to account for online instruction, assessment of students online, and tools (e.g., technology issues, virtual meeting tools, video tools for delivery, and digital tools for instruction). Although "sense of community" was not one of the top repeating ideas in our survey results—possibly because some sense of community had been established before the transition to ERT—the Richardson et al. (2017) meta-analysis indicates that social presence is an imperative topic for online instruction. If about 70% of the MTEs that participated in this survey research were teaching 100% in-person prior to ERT, then it is plausible to say that many educators in current teacher education programs have limited experience with creating quality online courses.

There are examples in the literature of successful remote teaching, and teacher preparation programs should draw from those (Goddard, 2020; Johnson & Merrick, 2020; Parker et al., 2020).

Skill development and new pedagogical strategies are not enough. The data also indicate that we must attend to less-concrete concerns that are connected to the emotions surrounding this change. If we are now expecting courses to be supported by an LMS like Canvas or video conferencing tools like Zoom, all faculty need help understanding the benefits of these applications while also highlighting the ways they can develop a supportive community environment. In their work, Johnson and Merrick (2020) also discuss the need for a feeling of community and connection during the pandemic, but through Zoom cafes: less-structured meetings among students and faculty that focus on students and their needs. Porath (2020) utilized a similar style of virtual meetings called CoffeeEdu, a relaxed atmosphere where preservice teachers and other educators met to discuss life during COVID-19. These studies and the results of this survey suggest that the outcome of the COVID-19 pandemic moving all instruction to remote instruction has implications for improving teacher education programs by emphasizing ways to support affective experiences and develop effective instructional strategies, including technology tools for online instruction. It is hoped that studies like these can lead to less nostalgia for past practices and more confidence in the benefits of the changes.

This suggested professional development for MTEs must extend to the preparation of preservice teachers in that preservice teachers must be prepared to teach online. The rapid transition to remote learning showed us that technology is no longer an add-on to our teaching. Therefore, technology must be integrated into every aspect of teacher preparation: assessment, classroom management, engagement, inquiry, methods, special education, diversity, etc. To illustrate, learning management systems (e.g., Canvas, Moodle, Google Classroom, etc.) are now an integral part of K-12 education, something unimagined just a few years ago. How do we best use them to assess student learning and communicate academic progress? Meeting software (e.g., Zoom, Skype, Meets, etc.) are critical tools for remote instruction or supporting quarantined students. How does our current knowledge of classroom management and effective instructional strategies translate over Zoom? What is the best way to manage a classroom discussion in an

online classroom? Supporting diverse learners and finding ways to provide inclusive classrooms must be an essential component of every teacher preparation program. How do issues of access to Wi-Fi and technology impact the ways students can engage in learning? We cannot expect teachers to answer these questions in isolation. This discussion must be led by solid recommendations from the research. This puts a heavy burden on MTEs to be sure that preservice teachers are ready to meet these challenges.

Our initial goal with this study was to capture the experiences and stories of MTEs during the unprecedented pedagogical shifts in the contextual learning environment that happened in spring 2020. As we analyzed the data, the authors wondered: if this event was unprecedented, what relevance do these stories have on the future of mathematics teacher education? Not knowing whether remote-only teaching is a thing of the past, we believe that our move toward increased dependence on remote teaching strategies and tools is inevitable. Therefore, it is imperative that teacher education programs incorporate this change, with an emphasis on TPACK development. Continued professional development is imperative for faculty in teacher education programs so that these programs continue to adapt and adjust according to the ever-changing needs and demands of our society. In turn, preservice teachers will be more prepared to teach in our dynamic and fluid digital society.

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