Chapter 31
Developing Teachers' Knowledge for Teaching in Virtual Contexts:
Lessons From the Pandemic of 2020–2021

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ABSTRACT

The 2020 worldwide pandemic signaled the COVID-19 crisis as a real threat and forced K-12 schools to move teaching and learning from face-to-face classrooms to online virtual classrooms. Educators searched for a silver lining amid the hardships created by the virtual teaching and learning environments. This chapter answers an important question: How has the knowledge that teachers need for teaching changed as a result of School Lockdown 2020-2021? Analysis of the chapters in this book in addition to extensive qualitative observations of two middle school virtual computer science classrooms over six months identified two important lessons needing consideration when requiring K-12 virtual instruction: (1) teachers' knowledge for teaching requires developing their technological pedagogical content knowledge for teaching in both face-to-face and virtual contexts, and (2) teaching virtually relies on a social presence that assures students' sense of belonging to engage in virtual learning experiences.

INTRODUCTION

Imagine that you are about to complete your college education with a secondary teaching license for teaching mathematics! What a delight to accept your dream job to teach middle school mathematics beginning in August. It is March 11, 2020 and you are finally paying attention to the world outside of

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finals and graduation. Suddenly, the World Health Organization declares COVID-19 a pandemic as a result of the significant increase in the number of cases outside China – over 118,000 cases in over 110 countries and territories with the very real potential for widespread community transmission. Can this possibly affect you and your plans? Obviously the answer is, "Yes!" Your graduation ceremony has been cancelled, but you will get your diploma, your teaching license and a middle school teaching position.

As you and most people worldwide realized, March 11, 2020 was the date when the COVID-19 crisis became real. The word pandemic gained new meaning! Suddenly, classroom doors were locked for the remainder of the school year and replaced with online instruction for the remainder of the school year. The scary part is that your first teaching position will most likely be a virtual teaching position. How long the instruction will be virtual is unknown. More importantly, you have never learned in a virtual environment and your teacher preparation program lacked any instruction for teaching in virtual environments.

Imagine how these revelations affected this graduating student who is about to enter the teaching profession. It will not be safe for schools to operate in face-to-face learning environments. Virtual instruction raised lots of questions as this graduate was about to enter a middle school classroom entirely online: How will this virtual environment operate? How will this change what she knows and understands about teaching mathematics to middle school students? How will the students gain the online access? Will she be asked to teach from home – to students entering from their homes? What kinds of technologies will be available for her and her students? There were so many unanswered questions at this point.

Fast forward to March 11, 2021. How did this first-year teacher manage teaching middle school mathematics in this virtual environment? What were the pedagogical challenges? How was teaching online different from her vision of teaching mathematics like she did in student teaching? Now, as teachers and their students returned to face-to-face instruction, did the instruction return to the old-normal regardless of what was learned? What best practices and pedagogical reasonings were gained from teaching virtually? At this point, many educators had lots of unanswered questions. What will happen in classrooms that return to face-to-face instruction? Do they return to teaching as they previously did? Or, have lessons been learned about new strategies for engaging students in learning? Have educators learned anything from the virtual instruction experience? Such questions prompted the goal for writing this book – to gather best practices and the pedagogical reasonings for responding to these questions after identifying what lessons have been learned.

While the chapters for this book were being written, Niess (the first author of this chapter) participated in a research project to examine the knowledge two middle school teachers relied on when teaching virtually. These two teachers were each adding a new course – a computer science (CS) elective course separate from their mathematics classes. Through observations of their work, Niess analyzed how teaching a new course virtually influenced their teacher knowledge – the transformation of their Technological Pedagogical Content Knowledge (also called TPACK). What challenges did these teachers face in teaching a new academic content in addition to shifting from face-to-face to virtual teaching? After analysis of their teaching, key themes from their virtual teaching experiences were identified. These themes were then aligned with the pedagogical reasoning and best practice themes collected from this book's chapters in response to two important questions:

1. How was teacher knowledge challenged as a result of School Lockdown 2020-2021?
2. What lessons were learned that teacher educators might rely on for preparing all teachers - preservice and in-service – for combining the best practices and pedagogical reasonings in virtual teaching with face-to-face teaching of K-12 students in the twenty-first century?

BACKGROUND

Emergence into the twenty-first century featured different tools, different communication, different information, and different professions. Expansion of computer-based, digital technologies generated many changes. The changes directed transformations in education with what and how students learn to become productive citizens in a new society punctuated by the influence of a more technological age. The changes created an acute concern about the knowledge that teachers need for teaching in the new century primarily supporting K-12 face-to-face instruction. What do teachers need to know and be able to do to engage students learning in more digitally-enhanced classrooms? How does access to new and more powerful digital technologies influence teachers' practices and pedagogical reasonings as they guide students' face-to-face learning?

Rather than focusing on technological features, affordances and constraints, scholars and teacher educators shifted their attention to teachers' thinking with respect to students' thinking, and pedagogical approaches in the context of learning with new technologies. Such redirection highlighted the importance of teachers' pedagogical reasoning and strategic thinking as well as their actions with respect to integrating technologies as learning tools. What was clear in this new century was that many questions confronted teacher education scholars as they reconsidered teachers' knowledge for teaching in the twenty-first century – a century clearly different from the previous one.

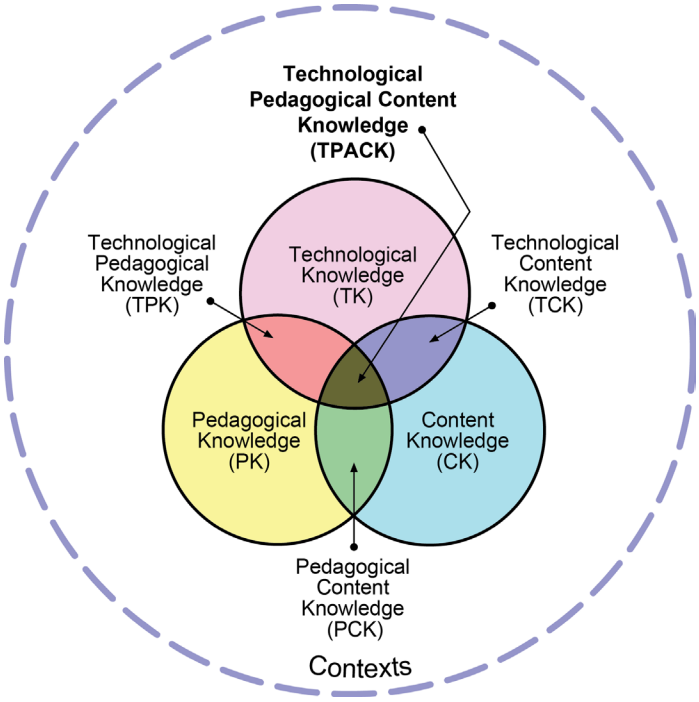
Teachers' Knowledge: Technological Pedagogical Content Knowledge

In this new century, Technological Pedagogical Content Knowledge (TPACK) emerged as a framework for describing the highly complex and challenging knowledge that teachers needed for teaching their content with appropriate digital technologies. Multiple researchers (Angeli & Valanides, 2005; Margerum-Leys & Marx, 2002; Mishra & Koehler, 2006; Niess, 2005; Pierson, 2001; Zhao, 2003) envisioned TPACK as the interconnection and intersection of content, pedagogy (teaching and student learning) and technology as shown in Figure 1.

This new teacher knowledge model highlighted multiple subsets immersed in the knowledge for teaching in this century: content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and finally, TPACK for technological pedagogical content knowledge. Another purposeful consideration in this framework was the emersion of these subsets within educational contexts, where "teachers' understanding of technologies and pedagogical content knowledge interact with one another to produce effective teaching with technology" (Mishra & Koehler, 2006, p. 12).

While the entire model was called TPACK, the center subset was also called TPACK. This duality promoted TPACK as either (1) the sum of the parts in the entire model or (2) as in Shulman's (1986) description of PCK, a transformation of the multiple subsets into the center TPACK intersection. The notion of this knowledge transformation envisioned the knowledge subsets as rearranged, merged, organized, assimilated and integrated such that they were no longer individually discernable – basically a new teacher knowledge that teachers relied on for designing and implementing curriculum and instruction, while guiding students' thinking and learning with various technologies in various content areas (Angeli & Valanides, 2008; Niess, 2005; Niess, 2013).

Figure 1. TPACK model highlighting its knowledge components. Reproduced by permission of the publisher, © 2012 by tpack.org



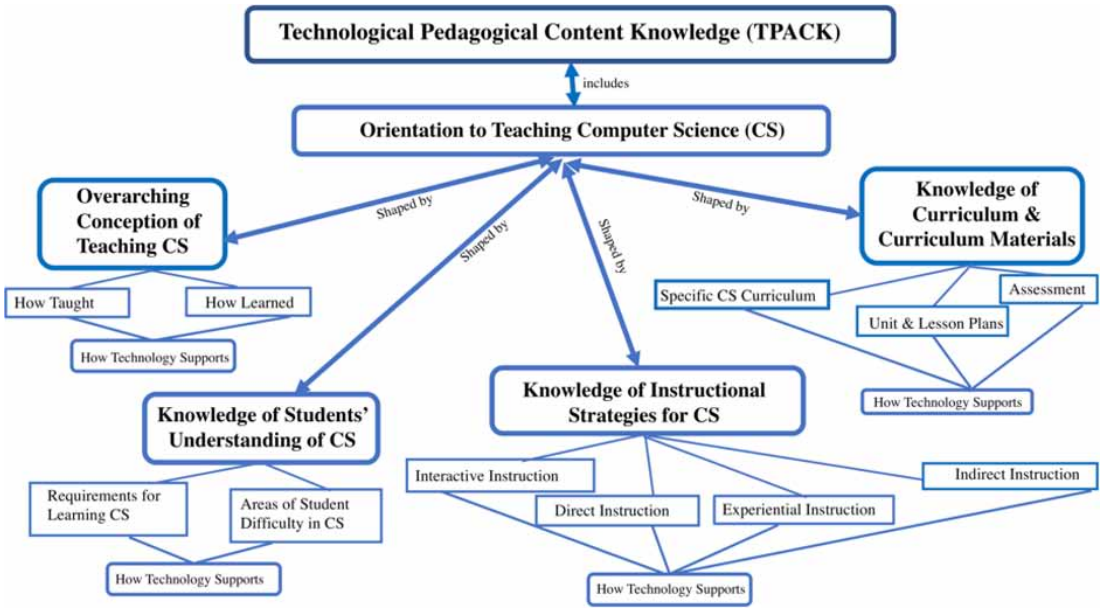
This chapter's research examined the knowledge that the two middle school teachers relied on when teaching a new course virtually. The challenge was to investigate the influence on their TPACK as a result of teaching virtually. Four components from Grossman's (1989, 1991) work with PCK guided this examination of this knowledge transformation as a result of teaching in a far more technological classroom environment (Niess, 2013). From this perspective, the teachers' TPACK was described through their:

1. Overarching conceptions about the purposes for incorporating various technologies in teaching multiple subject matter topics.
2. Knowledge of students' understandings, thinking and learning in subject matter topics with various technologies.
3. Knowledge of curriculum and curricular materials that integrate the technologies in learning and teaching subject matter topics.
4. Knowledge of instructional strategies and representations for teaching and learning subject matter topics with technologies.

These four components were further described in Figure 2, providing a method for examining these teachers' TPACK (Niess, 2013). For considering their overarching conceptions of teaching their subject matter (in this case computer science), the observers considered how they taught computer science (CS) and how students learned CS with particular attention to how multiple technologies assisted in each CS topic areas. Another important knowledge aspect highlighted students' understandings in CS. The observers examined the requirements for learning CS in relationship to student difficulties in understanding the

relationships as well as how the various technologies supported or detracted from their understandings. To determine the teachers' knowledge of instructional strategies for the content, evidence from multiple instructional formats (interactive, direct, experiential and indirect), the observers contemplated how the technologies supported different instructional strategies.

Figure 2. Strategy for examining teachers' TPACK knowledge



Additional scholar background assisted in clarifying the influence on the teachers' knowledge as they designed, taught, assessed and reflected on the results of their instruction. Niess et al. (2008) proposed a developmental model for TPACK stemming from Everett Rogers' (1995) model of the innovation-decision process. Rogers described a five-stage, sequential process by which a person makes a decision to adopt or reject a new innovation. Niess et al. (2008) reframed this process in terms of teachers learning to integrate a technology that they had not yet incorporated in teaching and learning the content. Over a four-year period, these researchers observed many teachers learning about spreadsheets and how to integrate spreadsheets as learning tools in their classrooms. The analysis resulted in a five-stage developmental process when learning to integrate a particular technology for teaching and learning:

1. *Recognizing* (knowledge), where teachers use the technology and recognize the alignment of the technology with the subject matter content but do not integrate the technology in teaching and learning of that content.
2. *Accepting* (persuasion), where teachers form a favorable or unfavorable attitude toward teaching and learning the content with an appropriate technology but they have not yet integrated the technology in teaching and learning of that content.
3. *Adapting* (decision), where teachers decide to accept the technology for teaching and learning and engage their students in activities to explore the content with the technology.

4. *Exploring* (implementation), where teachers actively integrate teaching and learning of the content with an appropriate technology.
5. *Advancing* (confirmation), where teachers evaluate the results of the decision to integrate teaching and learning the content with an appropriate technology.

Teachers' Knowledge for Teaching in Virtual Contexts

A key feature often overlooked in the TPACK knowledge model is the **context** in which the subsets are immersed. Porras-Hernández and Salinas-Amescua (2013) recognized the importance of context in the TPACK model. They described context as an important part of teacher's knowledge where it is situated within their reflective practices and related to their core beliefs and assumptions. More specifically, they declared that the context of teacher's knowledge referred to any of the following: (1) students' characteristics; (2) classroom and institution conditions for learning; (3) situated teaching activities; and teachers' epistemological beliefs. From this perspective, they described three context levels: micro, mezzo and macro. The micro level context was described as the in-class conditions for learning – a level that resonated most closely with the shift to the virtual learning context into which teachers were propelled by COVID-19 pandemic. They noted that:

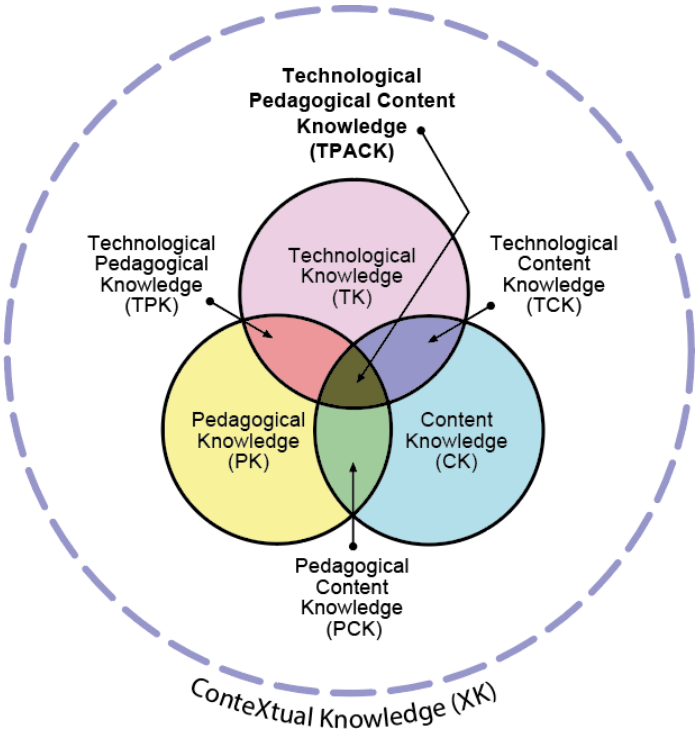
these conditions may involve available resources for learning activities, as well as the expectations, beliefs, preferences, and goals of teachers and students as they interact. Usually this is the context in which teachers feel most comfortable and perceive greater independence. (Porras & Salinas, 2013, p. 230).

Mishra (2019) drew attention to how the idea of contexts was included in the model. He noted that, in the model, Contexts were not designated as a form of knowledge in the same manner as the other subsets. To maintain consistency with the model, he revised the TPACK image as in Figure 3, replacing Contexts with ConteXtual Knowledge (XK). With this change, the model denotes that teacher educators can act on, change, and help teachers develop XK with respect to technology integration. Furthermore, the selection of the acronym XK is reasonable since X is typically recognized in mathematics as a variable, to give the notion that contextual knowledge is often highly variable.

With the COVID-19 challenge, this redesign of the TPACK model now shifts the attention to Contexts as ConteXtual Knowledge (XK). Teachers are now challenged and expected to teach in online environments - environments that rely on technological advancements for communicating with students. These environments present a significantly different context from that in which teacher's knowledge for teaching developed. What does this shift in context mean for the teachers' TPACK?

The important point about the timing with the sudden requirement to teach totally online was that the identification of a virtual context was definitely not the context in which today's teachers had developed their knowledge for teaching. They had gained knowledge about teaching throughout all of their learning experiences – their K-12 classroom learning as well as their college learning. For the majority of today's teachers, their learning experiences were primarily within the context of face-to-face educational experiences. Few learning experiences, if any, involved them in learning online. Their teacher preparation likely involved face-to-face courses and practicums. Their student teaching experiences were likely in face-to-face classrooms. All of these experiences have suggested that today's teachers learned about teaching within the context of face-to-face experiences. Think carefully about what this identification means. Their PCK developed primarily within face-to-face contexts suggesting that their

Figure 3. Revised version of the TPACK image © Punya Mishra, 2018. Reproduced with permission



TPACK knowledge developed through ideas based within the context of face-to-face learning experiences. Furthermore, teachers teaching over the past several years have likely expanded their TPACK in face-to-face environments. In other words, the majority of teachers teaching in 2020 learned to teach within the context of what it means to teach in face-to-face environments – not virtual environments!

The influence of a virtual micro context on teachers' knowledge underscores the challenge for the teachers in March 2020-2021. These teachers were not prepared to teach in a virtual context, a context that called for the use of many new technologies that evolved with the digital age of the twenty-first century. More importantly, recognition of the fundamental change in the micro context now called for transforming all the subsets of the TPACK model (including XK) to reframe and rearrange teachers' understandings for teaching in virtual contexts. Managing student engagement in learning became significantly different in the virtual classroom from that in face-to-face classrooms. This shift might be envisioned as moving from a three-dimensional classroom where teachers can move around the classroom to interact with students to a two-dimensional classroom where teachers can only see the digital faces of the students but are not able to move around the classroom as they were able to do in face-to-face classrooms. This recognition raises another question. How does such a virtual shift impact teachers' knowledge for designing and planning for engaging students in communication and collaboration for exploring various subject matter topics?

EXAMINING TEACHERS' VIRTUAL TEACHING EXPERIENCES

In Fall 2019 Niess (the first author and a co-principal investigator in a three year National Science Foundation project) collaborated in a researcher-practitioner partnership (RPP) to design a new middle school computer science (CS) curriculum to guide middle school students' understanding of basic CS concepts such as abstraction, representation, types and algorithms without an emphasis on coding. The project researchers, a middle school vice principal, a sixth grade mathematics teacher (Teacher A) and a seventh grade mathematics teacher (Teacher B) collaborated in the initial design of a CS elective curriculum for the upcoming sixth and seventh grade students beginning Fall 2020. By June, the team had completed a preliminary curriculum and were engaged in developing instructional strategies while each teacher prepared plans to pilot the basic curricular ideas in their one-week middle school summer camps.

Unexpectedly, the COVID-19 pandemic required a shift from face-to-face camps to virtual camps. Each teacher had at most two weeks to shift their instructional plans for teaching three hours per day over five days with students attending virtually through Zoom. This change required them to shift their pedagogical reasoning and thinking from face-to-face delivery to virtual experiences. The first author observed each of the camps in their entirety, conducting debriefs for at least one hour after each class. Once concluded, Teacher A prepared the full design of the sixth grade curriculum and Teacher B prepared the full design of the seventh grade curriculum. Each teacher then taught extended versions of the camp in their school-based classes virtually for at least the first semester (September 2020 – January 2021). Throughout this semester, Niess observed virtual classes at least once each week for the sixth and seventh grade classes, conducting debriefs after each observation. Data were gathered through these multiple observations focused around an examination of the two teachers' knowledge development and pedagogical reasoning growth for teaching in a virtual context. The primary research questions for the analysis of the observation data were:

1. How did the virtual context challenge the teachers' knowledge of technology, pedagogy and content when teaching the CS content?
2. How was each teacher's TPACK challenged when teaching the first semester CS content in the virtual context?

Teachers' Academic Preparation and Professional Teaching Experiences

The vice principal had specifically recommended the sixth and seventh grade teachers because of their solid teaching knowledge and their excitement for learning and then teaching CS. Both teachers had a strong mathematics content knowledge with extensive preparation for teaching middle school. The sixth grade teacher (Teacher A) had completed an elementary teacher licensure program, was teaching sixth grade mathematics and piloted the first summer camp that guided algorithm development to describe the rules for tabletop games such as Tic Tac Toe. The seventh grade teacher (Teacher B) had completed a secondary teacher licensure program with an undergraduate major in mathematics and a graduate degree in teaching mathematics. He taught the second virtual camp that extended the game-designed algorithms to programs in the Board Game Language (BoGL, 2020). Each teacher's TPACK for teaching mathematics was assessed to be at the Advancing level; they consistently evaluated the results of their decisions when teaching mathematics content with appropriate technologies. However, neither teacher had academic preparation in CS prior to their participation in this project. Their participation in the RPP

from Fall 2019 guided the development of their CS content knowledge. Thus, their TPACK for teaching CS at the beginning of this project was assessed at the Accepting level where they demonstrated a favorable attitude toward teaching and learning CS with appropriate technologies.

Data Sources and Evidence

Individual teacher case binders (Meyers et al., 2003) were compiled throughout this research semester, including all lesson plans, PowerPoints, worksheets and other materials for the new CS curriculum. The binders contained each teacher's reconfigured lesson plans for each class day, observer notes and debrief reflections for all observed classes. Qualitative analyses of the case binders used a whole-to-part inductive approach (Erickson, 2006) to identify patterns and themes in the experiences, discussions and reflections to capture and assess each teacher's progression and experiences. These analyses captured evidence of how their virtual thinking and pedagogical reasoning reframed their four TPACK components as proposed by Niess (2005, 2013) and divulged results for the two research questions.

Research Question One Results

The first research question probed how the virtual classroom instruction differed from face-to-face instruction with respect to the technologies, pedagogies and content in the instruction. The students were in either sixth grade or seventh grade in the middle school. During this fall semester, the sixth graders were new to middle school, entering from various elementary schools in the district. As sixth graders, they were unfamiliar with middle school classroom settings where they must move from one class to another with each class taught by a different teacher. This new setting was unlike their elementary classroom experiences where they primarily stayed in one classroom with one teacher teaching the multiple classes in the curriculum. These sixth grade students were, therefore, unfamiliar with most of the students and teachers in their newly assigned classes. On the other hand, the seventh graders had attended face-to-face classes in this middle school during the previous year. They had some familiarity with how instruction happened in middle school face-to-face classes as well as the virtual classes that ended their sixth grade year. They were not familiar with the seventh grade teachers or how the virtual classes might be taught during this new school year.

Beginning September all school classes opened virtually after assuring that all students had appropriate internet access along with district-provided and supported iPads. One hour classes began at 10 A.M. with 10 minute breaks between classes, a lunch break in the middle of the day, and the final class ending by 3:30 P.M. The seventh grade CS class was the first class of the day while the sixth grade CS class was the last class of the day. Students attended these virtual classes Monday, Tuesday, Thursday and Friday. Wednesday had shortened classes of 30 minutes, ending by noon to provide teachers with the remaining time during the school day for grading and communicating with students and/or their parents as needed. This schedule continued throughout the first semester.

Technologies

By its very nature, the virtual instruction depended upon the integration of multiple technologies. Students and their teachers used personal internet computer connections. Both teachers were suddenly transitioned to virtual teaching of their mathematics classes during the previous spring. By the fall semester, they

had little time to redesign and implement virtual plans for all of their fall semester classes. They relied on multiple technologies to enhance the virtual learning experiences for hopefully engaging the students in active, student-centered learning experiences. Both teachers depended on the school district's supported virtual framework: a Canvas studio site housing all information with links for the school and class schedule, introductions, Zoom, Padlet and Google accounts. The teachers tried Zoom polls to gather students' thinking after multiple 5-10 minute PowerPoint presentations. Since tabletop games motivated the CS content, they used electronic game versions, such as those offered through Tabletopia (2020). The students played as a whole class or in small groups in breakout rooms. Other internet-based games, such as Kahoot! Games (Kahoot, 2020) allowed for students' brain breaks when transitioning to new activities. For active learning experiences, the students used various internet technologies. For example, to engage the students as storytellers to describe specific game rules (such as Tic Tac Toe), students were challenged to create game stories using emojis from an electronic keyboard (https://emojikeyboard.io). Both teachers used other technological resources (such as district supported and approved educational videos) for active student engagement in exploring various CS concepts. The teachers consistently tried to incorporate activities to guide students in learning how to use the different technologies as well as how to learn with those technologies. This challenge limited the number of new technologies as well as the time needed for the CS curricular experiences.

Since students connected to the virtual classes from their homes via Zoom, the district was concerned about student privacy given the diversity and economic conditions. Some students used their iPads in their own room while others worked in a central home location. Often students were completing chores or caring for younger siblings while participating in the Zoom classes. With the level of diversities and disparities, the students were allowed to have cameras off which resulted in the display of avatars for their representations during the classes. While some students were comfortable with cameras on, what the teachers and other students more typically viewed through Zoom was a screen as in Figure 4. They could see names but not accurate renditions of the students.

Figure 4. Classroom Zoom display of a virtual class with cameras off displaying student avatars

Pedagogies

Without the ability to personally see each student, the teachers consistently had pedagogical challenges when trying to engage students in active learning experiences. The technological demands required extended instruction to guide students in accessing and operating the technologies through the Zoom transmissions as well as for using it as a learning tool. Instructional time was extended with teachers' questions as they checked for understanding. While both teachers wanted to incorporate student-centered pedagogies, the format of the virtual instruction quickly shifted to a more teacher-centered one, with teachers doing most of the talking and explaining. They found they needed to teach students multiple ways for communicating virtually with the class, such as by using the Reactions feature of Zoom to raise their hands or by entering comments in the Chat. Both teachers tried engaging all the students in the activities, calling on specific students to answer questions. Often this strategy failed to get a response for a variety of possible reasons – the student was not actively listening, might have moved away from the screen, might have been helping siblings, or might have been using the restroom. In any case the teachers used extended wait-times trying to encourage responses but often had to move to other students for responses.

For another strategy teachers used breakout rooms, organizing small groups to collaborate on specific tasks. Here again this strategy was often met with silence and inaction. Students were not used to working collaboratively in a virtual environment without a group leader. Using a jigsaw method to assign specific tasks to students in each group only worked with some groups while again many groups were silent. The silence might have been that they did not understand the directions, did not know how to begin the task, or might not have even been behind their avatars. Teacher A often used Padlet to overcome some of these challenges. In one case, she arranged the class in multiple groups of 2 or 3, asking students to work on the Padlet portions assigned to their groups. With this assignment, the groups entered ideas for pros and cons of certain methods for completing a task. During this process, they were able to see what the other groups were posting, thus giving them additional ideas. Teacher A was pleased with these student interactions.

The teachers were constantly concerned about engaging students in the classroom activities and discussions. In these virtual classes they recognized that students were unfamiliar with each other and had difficulty interacting. This problem was particularly pronounced for sixth graders. These students had not had opportunities to meet each other personally. They were shy in a new school situation. Working in small groups was difficult. They resisted speaking, waiting until someone was brave enough to say something to start the discussion. The teachers tried to create activities to engage the students but these strategies were typically met with silence where the teachers could not see if the students were paying attention, were off-task, or not even behind the avatar.

Engaging students in discussions and collaborations was a consistent challenge in all the virtual classes. The teachers were left wondering if students were engaged with the instruction, had questions they were uncomfortable asking, or were totally disengaged. Also, the district had insisted that throughout the virtual instruction as long as students eventually submitted assignments, those assignment were to be graded with no penalty. Despite teachers' reminders, only a small portion of the class submitted assignments by the due date, with others either submitting assignments late or not at all. Teachers often used the Wednesday afternoons for emailing or talking with students and/or their parents, trying to encourage more participation in the class. The teachers claimed the inaction might have been a result of Zoom fatigue through the multiple classes during the day.

Content

The CS content of the class was students' first interaction with CS. Tabletop games were intended as motivation since students had experiences playing many of the games such as Tic Tac Toe, Connect 4, Battleship, Monopoly, etc. However, the virtual environment required the inclusion of additional technologies for playing the games. The additional technologies actually increased the content with the need for guiding students in playing the games.

The teachers relied on stories to describe the games and the rules. They either played the games as a class or in pairs in breakout rooms. Then, they discussed the concept of *representations* in the game (such as X or O versus different colored Lego figures for playing Tic Tac Toe). For the concept of *abstraction*, the students were assigned to pictorially present three levels of abstraction to represent themselves as game players; the final level was to be a selfie. The discussion then moved to thinking about the concept of *abstractions* through the various story *representations* in the game. Ultimately, the class translated the rules of the game into *algorithms* to more clearly describe how the game was played using language more connected with CS algorithms, such as in control structure language using IF-THEN-ELSE and WHILE statements.

An important aspect of the content was that the virtual CS class curriculum was only one part of the school curriculum for this semester. While the students had other classes such as math and language arts, the overall middle school curriculum included opportunities for students to interact and meet each other, to help them build a sense of belonging with other middle school students. In a face-to-face school situation, this part of the curriculum normally happened during classroom transitions, where students visited their lockers and interacted with different students. In this virtual classroom environment, such transitions did not happen. Instead, the students simply interacted with whoever was at their home, that is if someone was home. Transitions from class to lunch did not provide the interactions that might happen in a lunchroom. In essence, the virtual curriculum did not provide opportunities for students to meet and interact with each other– opportunities to make friends that leads to building a sense of belonging in the school as well as in their classes. The virtual instruction for the sixth and seventh grade CS classes lacked opportunities for establishing this sense of belonging as described by St-Amand et al. (2017). Students saw each other's avatar more often than seeing each other's face when the class communication and collaboration happened and that communication was more likely with the teacher rather than with other classmates.

Research Question Two Results

The second research question highlighted challenge for the teachers' TPACK for teaching the CS content in this virtual context. Prior to this semester, these teachers had primarily taught mathematics, a content with which they had extensive academic instruction background. All of their experiences teaching mathematics used face-to-face classroom instruction. Both teachers clearly demonstrated a solid TPACK for teaching mathematics – in face-to-face classrooms where they demonstrated solid pedagogical content knowledge for teaching mathematics.

In this virtual semester, they were assigned to teach some mathematics classes in sixth or seventh grade with the addition of this new CS class with which they had limited content knowledge. During their experiences with the RPP, the virtual pilot teaching and this semester's virtual teaching experiences, the teachers were actually developing and extending their understanding of CS content. They were provided

with many lessons and activities but they now needed to consider how to use the materials in their virtual classes. Basically, these teachers were teaching in a situation where their content knowledge (CK) was different, and, more importantly, how their contextual knowledge (XK) was changed as a result of the virtual instruction. These changes clearly disrupted their TPACK.

The Teachers' Overarching Conceptions

While both teachers demonstrated and voiced clear overarching conceptions for teaching mathematics, during this semester both relied on their brief experiences with the CS curriculum from the summer pilot camps, leading to an uncertainty as to the direction for extending the concepts beyond what they taught in their lessons. During this first semester, both teachers depended on the prepared materials and directions from the researchers rather than creating many lessons of their own. Their overarching conceptions displayed a tentativeness in understanding CS concepts as they guided students in exploring the prepared materials. Teacher A had the advantage that the majority of her curriculum matched what she taught during the summer pilot camp. Also, she taught her sixth grade CS class in nine week sessions, allowing her to repeat the class the second nine weeks. This repetition enhanced her CS knowledge and understanding. She made notes about what worked and what did not work during the first session and made adjustments in the second session. Teacher B's seventh grade class extended for the whole semester for guiding the students in BoGL programming. He described his concern that he did not have the full understanding of the CS concepts and was certain he had some misconceptions in his basic understanding of CS as he tried to guide students' progressions in the board game algorithm development during this first semester virtual instruction.

The Teacher's Knowledge of Students' Understandings

With respect to their knowledge of students' understandings, thinking and learning in CS, the length of the virtual camps limited the teachers' opportunities to gather students' thinking, understandings and conceptions about the ideas. Both teachers expressed difficulty during the first semester for helping students develop the understandings and thinking. Rather than challenging students to share their thinking with the class, Teacher A used virtual notecards to describe the concepts of representation and algorithm. She followed this description by placing the students in breakout groups to summarize the ideas. However, as was more typical with virtual breakout groups, this expectation was more often followed with silence rather than sharing of understandings. The virtual experiences also constrained Teacher B as his preferred instructional strategy was to present the ideas, then ask students questions to gather their understanding and thinking. After this instruction, he typically sent them to breakout small group activities to expand on the ideas. He explained that in his mathematics classes he was able to engage students through questioning to guide their thinking, but with the CS curriculum, he was unsure of the best way to accomplish this type of lesson other than simply telling them the ideas. He openly admitted that his knowledge of the content was at a naïve stage. He recognized that with experience he would gain a more in-depth understanding of students' understandings and thinking and which activities and strategies helped them learn the important concepts. As with Teacher A, he was often caught in the dilemma of when to let them struggle with the ideas to enhance their learning and when to simply tell them what they should know. Ultimately, neither teacher had a solid grasp of students' understandings and how they might react to the concepts.

The Teacher's Knowledge of the Curriculum

The teachers' knowledge of the curriculum and curricular materials for teaching and learning CS was obviously directed by their experiences in working with the RPP work for developing the curriculum. Their knowledge depended on the lessons the researchers designed. Both teachers relied primarily on these prepared materials. Teacher A was successful in breaking the curriculum into smaller pieces. She augmented the game aspect of the curriculum with existing websites such as MathIsFun and Tabletopia for multiplayer tabletop games to provide students with more interaction. For writing algorithms from game rules, she designed some new worksheets and Powerpoint slides to guide the students in creating an algorithm for Tic Tac Toe and NIM. Teacher B primarily used an electronic whiteboard to explain the ideas and then organized the students in pairs to complete worksheets and programming activities. For both teachers the challenge of having to teach virtually forced them to use the prepared materials rather than designing their own. Their efforts were primarily focused on activities to keep students engaged in the virtual format.

The Teacher's Knowledge of Instructional Strategies

Each teacher's knowledge of instructional strategies and pedagogical representations for teaching and learning CS was confounded by the virtual teaching format with which they had little experience. Teacher A used multiple technologies to facilitate interactions and collaboration for engaging the students in thinking about the rules for the games. She did use Google applications for having the students collaborate on worksheets in Zoom breakout rooms and had success with a few students sharing their desktops from their group work. Teacher B relied almost exclusively on the whiteboard and PowerPoints to guide the algorithm development. After his presentations, the students worked in small groups to describe algorithms for the game rules. For closure the students shared their algorithms with the whole class. However, the virtual environment was not as conducive for the discussion that he hoped to have happen. Basically, with the challenge of the students' reluctance for sharing along with the Zoom organization that directed more student-teacher interactions rather than student-student interactions, both teachers consistently worked to engage students in multiple activities that they hoped would encourage interactions toward building an understanding of CS. Both teachers were frustrated with the inability to engage the students in collaborating and sharing ideas.

The Teachers' TPACK Knowledge

The teachers' TPACK for teaching CS was compressed when teaching the first semester CS content in the virtual context. Their CS content knowledge was fragile. They consistently requested that the researchers provide more clarity with respect to major concepts for the two classes. They relied heavily on the lesson plans and directions for their instructional plans. Their strength was in their understanding of middle school student learning needs. They had a clear understanding that these students needed multiple activities for engaging them in developing the conceptual ideas. Ultimately, they tended to think in terms of activities the researchers used in helping them understand the primary CS concepts.

The final analysis was that during this first semester, the teachers operated at the Adapting TPACK level, such that they had accepted the challenge for teaching CS and were actively engaged in teaching the CS class. At this juncture, they relied on the activities that helped them develop their own personal

understanding of the main concepts. The exception to this identification was that Teacher A had the opportunity to teach her class more than once. She had had the opportunity to develop her understanding. She began to redesign activities based on her realization of the CS concepts she was teaching as well as students' understanding that she had gathered through the curriculum and instruction during the first class. This shift indicated that she was moving into the Exploring TPACK level where she actively integrated teaching and learning of CS.

However, that strength was diluted with the challenge of teaching virtually. Both teachers continued to struggle with not being able to actually see their students and to easily interact with them as was more typical in a face-to-face class. Teacher A worked tirelessly to interact with each student in her class of 28 students. She consistently kept track of connecting with every student in the class in some manner, challenging them to use the Reaction features or to send her messages in the chat. She constantly reminded them that she wanted to hear from everyone during the class. Teacher B noted that with the Zoom façade, he simply could not tell if the students were on-task or even behind those avatars.

Neither teacher had been prepared to teach virtually. All of their preparation for teaching had been in a face-to-face context from their own K-12 and college level instruction. Their teacher preparation involved face-to-face instruction with a focus on face-to-face strategies and methodologies. They had learned about pedagogies for engaging K-12 students but those pedagogies presumed face-to-face engagement. Thus, their TPACK was a knowledge framed within a face-to-face context. Now their knowledge was challenged by teaching in a different context. Their TPACK was disrupted by the change in both their Content Knowledge (from mathematics to CS) and ConteXtual Knowledge (from face-to-face to virtual). They had a solid understanding of middle school students' understandings and learning needs. They had a solid understanding of pedagogies that would support those understandings and needs. However, the shift to virtual instruction disrupted the TPACK they had for teaching mathematics prior to teaching CS.

LESSONS FOR K-12 VIRTUAL EDUCATION: EMERGENT THEMES AND OVERARCHING IDEAS

The rapid K-12 educational shift to virtual instruction left many people lacking confidence that students would learn what they needed to learn during the pandemic year. The speed of the transition prevented teachers from having time and support for developing the pedagogical knowledge and skills to engage students in the unfamiliar virtual context. According to Pew Research Center surveys (https://www.pewresearch.org), more than 60% of Americans indicated that K-12 students were falling behind because of virtual classrooms. Examinations of online features and organizations for virtual instruction warned that these environments lacked key elements for guiding students in learning what they needed to learn. The challenge is whether there are lessons to be learned about teaching virtually from this global pandemic educational experiment. Are the bold claims true that K-12 students are not able to learn in online virtual environments? How has the knowledge that teachers need for teaching changed as a result of School Lockdown 2020-2021? Two important lessons for K-12 virtual education emerged from this 2020-2021 pandemic.

The Importance of Social Presence

Shifting to virtual instruction appeared to be the most reasonable solution for immediately protecting teachers and students during the pandemic. Businesses had used Zoom software to network throughout the world. Many colleges had offered online courses and entire degree programs to provide more access to higher education. Social media advancements had resulted in a multitude of technologies for social interaction that might be leveraged for online classrooms. Surely K-12's use of virtual instruction for all classes in particular situations might be possible. All they had to do was assure internet and computer technology access at least for each household. However, what to teach and how to teach in this virtual environment loomed as a huge concern for K-12 administrators, teachers, parents and students.

Zoom and learning management systems such as Blackboard, Canvas, Google Classroom, and Seesaw are available to support teachers in designing and delivering content through videos, PowerPoints and other smartboard technologies. The various chapters in this book have highlighted best practices for using multiple technologies for engaging students in communication, collaboration and cooperative learning. Google Suites' Jamboard allows students to simultaneously use a whiteboard or poster that automatically saves all changes added to the document. Small groups of students can enter text, draw, write, add pictures and even add sticky notes while collaborating in the development of a response to the teacher's questions about new ideas. With the Padlet website, teachers can set up web spaces for multiple small groups of students to add examples that expand on various key points in the topic for the day. For engaging the whole class in discussion, students can anonymously provide feedback responses in Mentimeter to challenges posted on a question slide. Teachers can set up discussion boards using Flipgrid to have students respond with a social media video to explain their thinking. Alternatively, teachers can establish a Bitmoji classroom experience by posting a slide to describe the learning experiences in which students are to be engaged as they learn new content. Bitmoji hyperlinks then connect students with different activities for the class. One link might send students to a Jamboard to collaborate in the creation of a poster while another might send a small group to work on a Google slide to prepare a presentation in response to a key question. In essence, each technology provides a way to engage students in exploring content ideas, where they are able to interact socially while communicating and collaborating in ways that build their understanding. At least these features suggest potential for engaging students in learning in virtual classroom environments.

Perhaps, an important lesson from these pandemic K-12 learning experiences has emerged as a result of how the multiple technologies provided pedagogical tools for the teachers to engage students in inquiry-oriented tasks for guiding students in communicating and collaborating while sharing their ideas and thinking. More importantly, these technologies stressed the importance of activating a social presence in K-12 virtual learning. Both teachers in the CS classroom observations wanted social interaction to support students in creating and collaborating in an exploration of the CS content. Both teachers used Google Slides and Padlet in small group breakout rooms to complete particular tasks. However, they consistently faced issues with a lack of student engagement, noting that more often than not, when the students returned from the breakout room activities, only a few students had made progress with the ideas while the majority of the students were unresponsive. As a result, closure to the lesson came from the teacher rather than the students. The lack of assignment submissions verified the lack of success for engaging students in communication and collaboration.

This important lesson recognizes the value of social interactions in virtual classrooms as described in the Community of Inquiry framework (Garrison et al., 1999). That framework projects the importance

of the interaction of three presences (teaching, cognitive and social) as key contributors to virtual educational experiences. Peacock and Cowan (2016) saw the importance of shifting virtual instruction from teacher-centered learning to student-centered learning. With this recognition, they shifted the teaching presence to a tutoring presence. For them, with student-centered instruction, the virtual teacher is actually a tutor who designs and plans what happens in class as a way of facilitating student engagement in specific actions towards achieving the learning objectives. The tutoring presence then facilitates the students in learning through both the social and cognitive presences (Akyol & Garrison, 2011; Garrison, 2017; Peacock & Cowan, 2019). From their perspective, the best practices with the various technologies not only supports the cognitive presence but also provides the pedagogical tools for furthering a tutoring role towards more student-centered instruction.

However, extenuating circumstances blocked actualization of the social presence in the observed middle school classes. The middle school students clearly demonstrated a lack of a sense of belonging as described by St-Amand et al. (2017). With the virtual beginning of the school year, the students attended the class through Zoom from their homes. There were no opportunities to meet and interact with other students in the school. When schools offered face-to-face instruction, the school day provided then with interactive opportunities. Yet, with their virtual classes with the camera-off displays, they were presented as avatars with name plates. When the class finished they were isolated in their homes. With the pandemic situation it was not safe to gather the students together socially. As a result, particularly for the sixth graders, there was little opportunity to gain a sense of belonging in this new virtual school situation. The teachers' efforts to encourage a social presence in the virtual class attempted to support students' sense of belonging in the academic environment. But, as an environment orchestrated by their teachers, the sense of belonging did not provide for individual student interactions through unstructured social activities, like meeting around their lockers, eating lunch with friends, gathering together after school, playing games like soccer, basketball, and baseball. In elementary school, the curriculum provided recesses where students interacted socially, met each other and learned to trust each other. Now, in middle school, there were no such freedoms before classes, between classes and after school.

Unstructured group interactions are important in the process of developing students' sense of belonging. This reality was clearly identified when the school moved to a hybrid framework following this virtual semester. The classes were modified and masked students returned two mornings a week in face-to-face, smaller, socially-distanced classes. Suddenly, the students actually saw each other and greeted each other with "Oh, that's what you look like!" The social nature of the afternoon virtual classes changed immediately with students interrupting the teacher as they interacted with other students – students that they now recognized! The lesson for virtual instruction underscored the importance of establishing a social presence where students were able to build a sense of belonging through the classroom interactions supported by both the cognitive and tutoring presences that supported the trusting, meaning-making and deepening understandings for a successful education experience (Peacock & Cowan, 2019; Peacock et al., 2020).

The Importance of Teacher Knowledge Preparation

The analysis of the teachers' TPACK for teaching CS was observed to be compressed when the teachers were teaching the first semester CS content in the virtual context. At that point, their content knowledge was under development as they were engaged in the research project. Now, they were required to teach a content with which they were unfamiliar and in a context with which they were unfamiliar. Their knowledge for teaching had been entirely within the context of face-to-face instruction. As a result, their

knowledge for teaching suffered as a result of a weakened Content Knowledge (CK) while teaching in a different context affected by their ConteXual Knowledge (XK).

As the K-12 educational system moves forward towards considering the potential offered by virtual instructional strategies, teacher educators must reconsider appropriate teacher education towards transforming K-12 teachers' knowledge for teaching to incorporate along with the face-to-face context advantages of virtual teaching. What program models might support future teachers as well as current teachers in gaining the skills, knowledge and beliefs that support teaching different subjects and guiding students in learning in virtual environments? What experiences are essential in building the knowledge and skills for teaching virtually? Questions such as these will continue to challenge teacher educators and researchers as they search for ways for meeting the new demands of teaching in the twenty-first century - teachers with a commitment to guide today's students to live, learn and work in the increasingly complex worldwide context.

The research and development towards building teachers' knowledge for teaching virtually has primarily focused on adult learners. The results from the observations of middle school teachers teaching CS during this past year exposed how different K-12 learners are from adult learners, differences that revealed the importance of establishing a social presence that positively supports the cognitive and tutoring (or teaching) presences for the ultimate success of virtual teaching and learning. Effective virtual instruction is clearly different from face-to-face instruction.

K-12 teacher education programs must consider both pre-service and in-service teacher education in addition to on-going professional development opportunities. The chapters in the book have suggested ideas for redesigning current teacher preparation programs. Teachers need preparation for developing the pedagogical practices and teaching strategies for teaching their content with instructional technologies in virtual constructs. Teachers need preparation that expands their knowledge for understanding the importance of how social presence affects student learning, not only in face-to-face environments but also in virtual environments. Teachers need opportunities to explore teaching in a virtual environment – not only in their pre-service programs. They need practices in both face-to-face and virtual contexts to recognize and reflect on the impact of different contexts. In-service teachers need support in understanding teaching with the new technologies that have supported virtual teaching experiences.

As Schulman (1986) lobbied for recognition of developing an integrated pedagogical content knowledge for teaching, teacher educators must pay attention to the influence of different contexts in which the teachers will be guiding student learning. The twenty-first century heralded significantly different teaching and learning contexts, adding more and more technologies to support and encourage human communication, collaboration and interaction in ways that were not fathomed in previous centuries. Thus, the lesson learned from School Lockdown 2020-2021 is the importance of teacher knowledge preparation and development. These technological shifts to education have highlighted the importance of establishing and building students' sense of belonging for the success of the learning experiences. While teachers might be mathematics or even CS teachers, their knowledge for teaching must be transformed to support them in attending to the influence of the social context that supports student interaction while they are exploring the content ideas with their classmates.

FUTURE RESEARCH DIRECTIONS

The research in online teaching and learning has primarily considered adult learners rather than K-12 learners. The body of that work has highlighted the importance of establishing a Community of Inquiry when teaching online (Garrison et al., 1999). The question remains as to the importance and/or value of establishing such a community of learners in virtual K-12 classes. The chapters in this book identify a variety of technologies and pedagogical strategies that can be useful for K-12 teaching virtually. However, extended observation of virtual teaching experiences has highlighted the concern about social presence in K-12 virtual instruction. More research needs to be done for determining how to establish and maintain a K-12 social presence that develops open and meaningful communication among the students and their teachers. Collaborative online learners need to learn how to interact socially in a K-12 virtual learning experience in ways that they are able to meet each other and trust each other as they explore ideas and develop understandings. Researchers need to examine the cognitive advantages emerging from teachers' technological strategies in support of this social presence in K-12 virtual learning. How does this instruction add to meaning-making and deepening of understandings?

CONCLUSION

This chapter began by imaging how a new teacher was thrust into teaching virtually when her entire teacher preparation was focused only on teaching in a face-to-face classroom. This chapter proposed identifying the impact of School Lockdown 2020-2021 on K-12 teachers' knowledge for teaching, including that of the first year teacher with no preparation for teaching virtually. Availability of more advanced digital technologies certainly provides opportunities for students to explore ideas as they interact socially, while communicating and collaborating in building and establishing their understandings. At least these features were identified as important for teaching virtually. However, as teachers incorporated the technologies for more student-centered activities in the virtual instruction, they found that if students were not connected they lacked the social presence needed for online interactive experiences. The pandemic forced K-12 schools to redefine teaching and learning, where all teachers, including first year teachers, struggled to identify instructional strategies that engage students in learning.

Much has been learned about teaching despite the challenges in teaching virtually. Two lessons emerged from the observations of teachers teaching virtually. Virtual teaching highlights the importance of the interaction among three key presences- teaching/tutoring, cognitive and social presences. With K-12 virtual teaching, attention to the social presence is particularly important with its relationship to students developing a sense of belonging that leads to academic success. This sense of belonging results in students' feelings of acceptance in the class as well as in small group activities. Teachers must provide opportunities for students to find and develop common interests with other students in the class. Without attention to developing students' sense of belonging in the class, the potential effectiveness of virtual education is deteriorated. This lesson leads to the second lesson that emerged from the observations of teachers teaching virtually. The preparation of teachers for teaching in K-12 is filled with experiences with face-to-face instructional strategies. They need experiences that develop the pedagogical reason-

ing and instructional strategies for virtual teaching. Teachers' knowledge for teaching without attention to this virtual context results in a weakened knowledge for teaching in the twenty-first century where the digital technologies advance learning in new and different contexts. Teachers need opportunities to explore teaching in a virtual environment – not only in their pre-service programs. They need to learn about and develop strategies for face-to-face and virtual contexts; they need to recognize and reflect on the impact of differences in the contexts. In-service teachers need support in understanding teaching with the new technologies that have come with the virtual teaching experiences.

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