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Mathematics teachers today face increasing expectations to integrate current and emerging technologies in their instruction while ensuring that technologies are supporting students in learning mathematics. Typically, these technologies are ones that the teachers

1. Are unfamiliar with,
2. Did not use in their own precollege education, or
3. Have received no instruction in their teacher preparation programs on how to integrate the technologies for teaching and learning.

In other words, the technologies require that the teachers and teacher candidates think outside their traditional views of how content is learned and communicated.

Adding to these expectations is a recognition of the advancements in understanding learning and teaching. Today’s predominant learning theory builds from a constructivist framework, highlighting the importance of the learner in building (or constructing) his/her knowledge (Piaget, 1970, 1976; von Glaserfeld, 1991). Supplementing this understanding, Vygotsky’s emphasis on social construction of knowledge describes social factors as having a central role in the transformative nature of learners’ internalizations of constructed ideas. Now, consider the value of metacognitive reflections on how and what learners construct. These ideas coalesce into a social metacognitive constructivist perspective on learning and teaching that directs student-centered collaborative learning in ways that “promote student reflection using collaborative tools to reveal and clarify students’ conceptual understanding and thinking, planning, and creative processes” (International Society for Technology in Education [ISTE], 2008, p. 1). The pedagogies for teaching mathematics with technologies have been and are part of the transformation of teachers’ knowledge for teaching mathematics in the digital age.

Thus, instructional designers, teacher educators, and professional developers are expected to design and offer programs, courses, and workshops to help transform mathematics teachers’ knowledge for teaching with technology – otherwise known as Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006; Niess, 2005, 2008; Thompson & Mishra, 2007). The TPACK theoretical framework projects new teacher knowledge as a knowledge that transforms teachers’ traditional knowledge, skills and understandings about teaching mathematics. This transformation is knowledge that has been rearranged, merged, organized, assimilated, and integrated such that the individual inputs (content, pedagogy and technology) are no longer individually discernible in the thinking and reasoning for teaching with technologies.
From the situated learning perspective, how and where a person learns is fundamental to what is learned (Greeno, Collins, & Resnick, 1996). Cochran-Smith and Lytle (1999) describe teachers’ knowledge-of-practice by focusing on the experiences in which the knowledge is developed. Three concepts are useful when thinking about TPACK development and the situation within which that development happens:

1. Knowledge-for-practice is the research-based, scholarly, formal knowledge for teaching, acquired through traditional instructional avenues such as in university courses; teachers’ practices use this “formal knowledge base in their daily work of the classroom” (p. 257);
2. Knowledge-in-practice is wisdom that teachers gain from the practice of teaching in classrooms, where what they know is embedded “in the artistry of practice, in [their] reflections on practice, in [their] practical inquiries, and/or in [their] narrative accounts of practice” (p. 262);
3. Knowledge-of-practice is knowledge gained through “systematic inquiry about teaching” with technology that considers “learners and learning, subject matter and curriculum, and schools and schooling” (p. 274). This knowledge-of-practice concept incorporates both the “for” and “in” aspects, integrating them in a manner that transforms teachers’ knowledge of practice for teaching with technology – their TPACK.

What learning experiences are needed to guide teachers’ knowledge transformation toward a knowledge-of-practice for teaching mathematics with technologies? Teachers’ learning experiences need to be factored with the recognition of multiple potential educational purposes toward which the learning is directed. It should also be recognized that the learning experiences may take place at the undergraduate or graduate level:

1. When learning mathematics in the preservice program;
2. When learning the preservice educational methods coursework;
3. When learning in the preservice practicum field experiences and student teaching;
4. When learning as an inservice teacher in professional development experiences;
5. When learning as an inservice teacher in graduate continuing education programs.

Another important factor in each of these cases is the consideration that educational situations vary from face-to-face to hybrid to fully-online learning experiences. If the programs involve inservice teachers, the programs must meet the broadly distributed locations where teachers have limited access to centralized educational programs. These teachers need professional development programs structured around their work lives in order to respond to the challenges of teaching with technologies (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). Therefore, more and more, colleges and universities are including online learning experiences in their programs. With respect to inservice teachers, professional development and graduate programs are now considering more asynchronous forms for the continued learning of teaching with technologies. And, of course, with the digital age, more and more mathematics teachers are being faced with teaching in online environments as well as face-to-face environments. To gain the needed experiences to support this type of teaching, they need online learning experiences focused around teaching mathematics with technologies.

An important consideration when designing online educational experiences is the idea of a foundational framework structure for the coursework design – an effective learning trajectory that considers the nature of online learning and yet responds to the challenges for social interactions in the learning
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experiences. Confrey and Maloney (2010) define a learning trajectory as: “A researcher-conjectured, empirically-supported description of the ordered network of experiences a student encounters through instruction (i.e. activities, tasks, tools, forms of interaction and methods of evaluation), in order to move from informal ideas, through successive refinements of representation, articulation and reflection, towards increasingly complex concepts over time” (p. 968). From this perspective, teacher educators and education researchers have been challenged to identify these researcher-conjectured, empirically-supported learning trajectories for the transformation of mathematics teacher’s knowledge for teaching with technologies. As Borko (2004) indicates, the importance of the process of identifying high-quality teacher change programs that result in effective transformations begins with studies in a single site while exploring relationships among teachers as learners in specific learning trajectories. Analysis of this evidence from these research studies is key to forming mathematics teacher preparation in the digital age. The challenge is to gather and analyze solid research-based evidence to inform future directions in transforming mathematics teachers’ and teacher candidates’ knowledge for teaching with technologies.

SECTION 1: FRAMING KNOWLEDGE FOR TEACHING MATHEMATICS WITH TECHNOLOGY IN THE DIGITAL AGE

In Chapter 1, Harrington, Driskell, Johnston, Browning, and Niess analyze the research literature regarding implementation of the Technological Pedagogical Content Knowledge (TPACK) framework in the preparation and support of mathematics teachers. The results indicate that TPACK has become a foundational framework in the research. Specific studies highlighted in this paper show that, while individual components of TPACK are illustrated in the literature, the field is still lacking sufficient examples of these components acting as a “total package” (Niess, 2008).

In Chapter 2, Dick and Burrill describe design and implementation principles for choosing and using dynamic interactive mathematics technologies to support mathematics learning and teaching. Illustrative examples are drawn from a collection of Building Concepts dynamic interactive documents designed to support the teaching of mathematics consistent with the Progressions for the Common Core State Standards for Mathematical Content and Practices.

In Chapter 3, Wiburg, Chamberlin, Trujillo, and Parra describe the design, development, and testing of a successful mathematics game-based intervention, Math Snacks, for students in grades 3–7. This program shows the impact of an integrative approach to developing TPACK, where interactive digital media are combined with inquiry-based activities in classrooms facilitated by teacher involvement.

In Chapter 4, Herbst, Chazan, Chieu, Milewski, Kosko, and Aaron focus on how digital technologies provide affordances for practice-based mathematics teacher education and map needed research on technologically-mediated teacher education. Using LessonSketch as a prototype of an online platform, this chapter describes what those pedagogies look like by narrating three cases of technologically-mediated, practice-based mathematics teacher education.

In Chapter 5, Driskell, Bush, Ronau, Niess, and Pugalee examine the contents of published mathematics education technology professional development papers over several decades using Sztajn’s (2011) standards for high-quality reporting in mathematics professional development research studies, the Technological Pedagogical Content Knowledge framework, and the Comprehensive Framework
for Teacher Knowledge. The Professional Development Implementation and Evaluation Model and the Education Professional Development Research Framework are recommended for further guidance in reporting key features of mathematics education technology professional development.

In Chapter 6, Hoyos reviews conceptual elements from the study of recent theoretical frameworks to analyze the preparation of teachers for teaching and learning mathematics. Specifically, a critical analysis is conducted about the peculiarities of the current online teaching and learning courses called massive open online courses (MOOC) available to support teachers in teaching mathematics with technologies.

 SECTION 2: DEVELOPING AND ASSESSING PRESERVICE TEACHER KNOWLEDGE FOR TEACHING MATHEMATICS WITH TECHNOLOGIES IN THE DIGITAL AGE

In Chapter 7, Cox and Harper report on a study of 39 preservice secondary mathematics teachers enrolled in a course on mathematical problem solving with technology. The results describe a vision for teaching with technology and reveal instructional experiences for the emergent vision.

In Chapter 8, Suh, Sprague, and Baker highlight a self-study of three university faculty members who sought to improve the design of an elementary mathematics technology integration course. The redesign resulted in performance-based assignments that better prepare teacher candidates to integrate technology into their mathematics teaching.

In Chapter 9, Edson and Thomas document two research studies examining the integration of digital instructional materials in teacher preparation programs. The results suggest that while effectively leveraging digital materials may require teachers to think outside of their traditional views of how mathematics content is learned and communicated, doing so requires more than the resources themselves.

In Chapter 10, Amador and Earnest report on a project in which elementary mathematics preservice teachers visualize lessons through an online animation platform. Project components emphasize the role of animations as an extension of lesson planning. The intent is to understand the ways in which the technology platform illuminates preservice teachers’ curricular decision making as they transition from written lesson plans to animated lessons.

In Chapter 11, Hollebrands, McCulloch, and Lee examine prospective teachers’ incorporation of technology tools in lesson plans. Algebraic topics and the graphing calculator were prominent in the lesson plans teachers produced over multiple mathematics methods courses. The results show that the preservice teachers positioned the technology as Servant or Partner (Goos, Galbraith, Renshaw & Geiger, 2000).

In Chapter 12, Edson, Rogers, and Browning examine elementary preservice teachers’ use of justification in problem-solving contexts based on a semester-long algebra course designed for elementary education mathematics minors. VoiceThread was the digital venue the preservice teachers used to listen to their peers’ justifications and post descriptive feedback. Findings showed a range of descriptive feedback with the potential to promote growth in the understanding and use of mathematical justification.

In Chapter 13, Flores, Park, Bernhardt, and Buttram describe an empirical study aimed to design, implement, and refine a learning trajectory for developing future mathematics teachers’ Technological Pedagogical Content Knowledge (TPACK). The learning trajectory is set in an instructional context where mathematics and technology are learned through inquiry, cooperation, communication, and modeling early in the teacher preparation program with the intent to establish a classroom model of instruction.
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In Chapter 14, Marshall and Callahan drew upon their knowledge domains, grounded in the TPACK framework and the Mathematical Knowledge for Teaching (MKT) framework, to design and utilize online discussion blogs as instructional tools to enhance preservice elementary teachers’ learning of geometry and measurement. The findings indicate that more attention is warranted on the interrelationships between TPACK and MKT knowledge domains, specifically when mathematics teacher educators engage in collaborative planning.

SECTION 3: TRANSFORMING AND ASSESSING INSERVICE TEACHER KNOWLEDGE FOR TEACHING MATHEMATICS WITH TECHNOLOGIES IN THE DIGITAL AGE

In Chapter 15, Polly, Martin, Wang, Lamert, Pugalee, and Middleton describe the design and influences of a yearlong professional development project focused on supporting primary grades teachers with formative assessment skills in mathematics. The professional development blended face-to-face workshops with classroom-based activities that were presented and facilitated through an online asynchronous format.

In Chapter 16, Bos and Engel address how teachers can be trained to support serious games for learning mathematics using the GaNA framework. The teacher is responsible for increasing game usage by designing deep mathematical experiences, providing abundant feedback, scaffolding experiences, and encouraging collaborative and creative play.

In Chapter 17, Hawley and Polly introduce InterMath as a learner-centered professional development environment that supports the development of Technological Pedagogical Content Knowledge (TPACK). From their study, the knowledge and skills of the professional development facilitator are key factors in the teachers’ development.

In Chapter 18, Niess and Gillow-Wiles propose an alternative methodology to the structure of traditional observations, where the Scoop Notebook provides a window into mathematics teachers’ knowledge-of-practice. This study illustrates how the Scoop process results in engaging teachers in action research where they use artifacts as objects to think with to transform their TPACK for integrating technologies in teaching mathematics.

In Chapter 19, Felger and Shafer share results of a classroom-based action research study on instructional decision making when teaching a unit on linear functions with GeoGebra, a dynamic algebra environment. The TPACK/Student Knowledge Matrix developed by Niess (2008) provides the structure for the unit planning and lesson development.

In Chapter 20, McBroom, Jiang, Sorto, Shite, and Dickey document the positive impact of the professional development for teachers’ Technological Pedagogical Content Knowledge (TPACK) development and their students’ achievement in geometry through the use of dynamic interactive computer software. Findings show that the teachers’ TPACK tended to remain within the three middle TPACK levels (accepting, adapting, and exploring) as they taught with this dynamic computer software. Recommendations and suggestions are provided for future research for school-based, mixed-methods research studies involving technology.

In Chapter 21, Pape, Owens, Owens, and Irving introduce the Classroom Connectivity for Mathematics and Science (CCMS) program to examine the efficacy of classroom connectivity technology in Algebra I. This professional development program supports participating teachers in implementing the technology. Recommendations are described for training teachers to implement the technology.
In Chapter 22, Gillow-Wiles and Niess present a reconstructed conception of learner engagement in online environments consisting of: engagement with community; engagement with technology; engagement with mathematics content; and an amalgam of all three. This model supports teacher educators in describing and evaluating how teachers as learners engage in a unit of instruction using technology, and in framing the course design and instructional strategy choices for supporting learner engagement.

REFERENCES


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