Chapter 17
Learning Mathematics and Technology Through Inquiry, Cooperation, and Communication:
A Learning Trajectory for Future Mathematics Teachers

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ABSTRACT

This chapter describes 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. The chapter focuses on preservice teachers' learning in two dimensions of TPACK. One dimension is the extension of preservice teachers knowledge to each one of the four principal components of TPACK: Overarching conceptions, Students understanding and thinking, Curriculum and curricular materials, and Instructional strategies and representations for teaching. The second dimension is along preservice teachers' progression in the five levels of adoption of technology: Recognizing, Accepting, Adapting, Exploring, and Extending. The learning trajectory is based on research and theory for learning mathematics in a meaningful way.

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INTRODUCTION

Current and emerging digital technologies create opportunities for students to learn mathematics through inquiry, collaboration and communication as called for in the *Common Core State Standards for Mathematics* (CCSS-M, Council of Chief State School Officers & National Governors Association Center for Best Practices, 2010) and the International Society for Technology in Education (ISTE) Student Standards (2007). However, these opportunities require the preparation of future mathematics teachers to use new instructional techniques that effectively integrate technologies for learning mathematics. This chapter focuses specifically on the design, implementation, and revision of a learning trajectory for preservice mathematics teacher preparation.

Learning trajectories interconnect developmental progressions and instructional sequences, and because of these interconnections, they are more complex and comprehensive than traditional scope and sequence analyses (Clements & Sarama, 2004). Learning trajectories integrate developmental progressions that (1) sequence increasingly sophisticated and complex types of thinking in a domain with (2) pedagogical progressions that describe appropriate types of tasks and learning activities geared for specific levels along the developmental progression (Barrett et al., 2012). They not only provide guidance for teaching a certain topic, but also for improving the assessment tools, and for designing and implementing professional development projects (Barrett et al., 2012). In addition, the focus on learning trajectories follows a key principle in comprehensive research-based curriculum development (Clements, 2002) as needed in preservice teacher preparation programs given the challenge of learning to teach with new and emerging technologies.

Designing a learning trajectory is a multifaceted and complex task where the growth of the students' knowledge is analyzed in different ways. For instance, researchers might describe ways that active use of technologies contributes to students' opportunities for conceptualizing mathematical ideas, with special emphasis on representing, generalizing and abstracting, and mathematical modeling. In this chapter, we focus on the development of preservice teachers' knowledge for learning and teaching mathematics with digital technologies, that is, on their development of the specialized teacher knowledge called technological pedagogical content knowledge. From this study, we designed and developed a learning trajectory for a new course in the first year of the college teacher preparation program to integrate the use of technology as a tool for inquiry, collaboration, and communication in learning mathematics. We designed and implemented the learning trajectory so that the use of technology helped make the learning of mathematics conceptual, active, social, multimodal, and symbolic/representational across geometry, algebra, trigonometry, and calculus, with a strong orientation toward scientific applications.

Two theoretical frameworks supported the design and refinement of the learning trajectory and were useful in analyzing preservice teachers' knowledge development. For the first framework, we relied on an enhancement of the Technological Pedagogical Content Knowledge (TPACK) construct (Mishra & Koehler, 2006) as described through specific TPACK central components (Niess, 2005, 2013). The second framework focused on the levels of adoption of technology, using the framework developed by Niess and her colleagues (Niess, 2015) deriving information from Rogers' (1995) seminal work on adoption of innovations. Although principles for learning mathematics for understanding were also a base for the design, implementation, and evaluation of the learning trajectory, in this chapter we used them to illuminate special issues in developing the knowledge for teaching mathematics with technology.