SUPPORTING PRESERVICE TEACHERS' USE OF CONNECTIONS AND TECHNOLOGY IN ALGEBRA TEACHING AND LEARNING

Eryn M. Stehr, Michigan State University
Hyunyi Jung, Calvin College

The Conference Board of the Mathematical Sciences recently advocated for making connections and incorporating technology in secondary mathematics teacher education programs, but programs across the United States incorporate such experiences to varying degrees. This study explores preservice secondary mathematics teachers' opportunities to expand their knowledge of algebra through connections and the use of technology and to learn how to use both to support teaching and learning of algebra. We explore the research question: What opportunities do secondary mathematics teacher preparation programs provide for PSTs to learn about connections and encounter technologies in learning algebra and learning to teach algebra? We examine data collected from five teacher education programs chosen from across the U.S. Our data suggest not all secondary mathematics teacher preparation programs integrate experiences with making connections of different types and using technology to enhance learning across mathematics and mathematics education courses. We present overall findings with exemplars.

Key words: Algebra, Technology, Connections, Secondary Teacher Training

Algebra plays a prominent role in mathematics education reform efforts because it is valued as a foundational subject in mathematics. Particularly in the United States, preparing future secondary mathematics teachers to teach algebra has gained importance as, in response to algebra-for-all initiatives, more states include algebra as a high school graduation requirement (Teuscher, Dingman, Nevels, & Reys, 2008). Due to these new requirements, not only are more secondary mathematics teachers teaching algebra in their first professional position, but these new teachers are also expected to teach algebra to a more diverse population of students than ever before (Stein, Kaufman, Sherman, & Hillen, 2011). Hence it is imperative that we study how teaching programs prepare preservice teachers (PSTs) for teaching algebra to this diverse population. Particularly important is attention to how future mathematics teachers are supported in developing a deep understanding of algebra.

This presentation is situated within a larger project that has used several different perspectives in exploring opportunities PSTs have to learn algebra and learn to teach algebra in teacher preparation programs. In this presentation, we have chosen to focus particularly on two ways that can support PSTs in deepening their own understanding of algebra, as well as supporting them in developing strategies for supporting their future students' algebra learning.

Standards for both secondary mathematics content and teacher preparation have emphasized the importance of developing PSTs' abilities to make connections and to use appropriate educational technologies in their own mathematical learning and in their future mathematics teaching. Particularly with respect to PSTs' mathematics courses, *Mathematics Education of Teachers II (METII)* recommended that instructors of mathematics courses support PSTs in "forming connections" (p. 56) and that experience with technology "should be integrated across the entire spectrum of undergraduate mathematics" (CBMS, 2012, pp. 56-57).

Standards developed for teacher preparation program accreditation agencies, such as Interstate Teacher Assessment and Support Consortium [InTASC] and National Council for Accreditation of Teacher Education [NCATE], have emphasized the importance of developing PSTs' abilities to see mathematics as a complex, connected system woven through other non-mathematical disciplines as well as a way to make sense of the real world (Council of Chief State School Officers [CCSSO], 1995; National Council of Teachers of Mathematics [NCTM], 2012). PSTs must think about mathematics as a "whole fabric" as they make connections among mathematical topics and in relation to others (NBPTS, 2010). To support this view of mathematics, PSTs need to make connections within algebra, and between algebra and other mathematical fields, while linking algebra with real-world situations. PSTs should prepare to teach using "rich mathematical learning experiences" and provide their future students with opportunities to "make connections among mathematics, other content areas, everyday life, and the workplace (NCTM, 2012). Further, PSTs should also be able to prepare to support their future learners in reflecting "on prior content knowledge, link[ing] new concepts to familiar concepts, and mak[ing] connections to learners' experiences" (CCSSO, 1995).

Teacher preparation standards have emphasized the importance of PSTs' own learning of mathematics content using technologies as both a "practical expedient" as well as to enhance learning. Teachers also need support in critically evaluating and strategically using technology in mathematics teaching and learning (CBMS, 2012; CCSSO, 1995; NCTM, 2012). In addition, *METII* emphasized the importance of PSTs' preparation for using a variety of technologies, including problem-solving tools and tools for exploring mathematical concepts (CBMS, 2012).

This study explores opportunities provided by secondary mathematics teacher preparation programs for PSTs to expand their knowledge of algebra by making connections and using tools and technology and to learn how to incorporate their own use of connections and technology when they teach algebra. We explore the following research question: "What opportunities do secondary mathematics teacher preparation programs provide for PSTs to learn about connections and encounter tools and technologies in learning algebra and learning to teach algebra?" Making connections in the service of algebra teaching and learning might include making connections within algebra, between algebra and other mathematical fields, between algebra and non-mathematical fields, and between ideas in advanced algebra and school algebra. Encounters with technology in the service of algebra teaching and learning might include using or learning about a variety of algebra-appropriate technologies, as well as thinking critically about technology use. In this study, we define tools and technology broadly as electronic tools and software, as well as physical tools such as manipulatives.

Method

This study is part of *Preparing to Teach Algebra (PTA),* a mixed-methods study that explores opportunities provided by secondary mathematics teacher preparation programs to learn algebra and to learn to teach algebra. The *PTA* project consists of a national survey of secondary mathematics teacher preparation programs and case studies of five universities. The current study is a qualitative analysis of the case studies focusing on the opportunities provided to PSTs to encounter technology and to make connections in learning algebra and learning to teach algebra.

The *PTA* project purposefully chose secondary mathematics teacher preparation programs at five universities to explore. We refer to these universities as Beta, Gamma, Kappa, Sigma, and Zeta Universities. Beta, Kappa, and Zeta Universities have Carnegie classification of Master's L (Master's-providing Colleges and Universities – larger programs). Gamma and Sigma Universities are doctorate-granting institutions with Carnegie classification of RU/VH (Research Universities – very high research activity). Beta, Gamma, and Kappa Universities are located in the Great Lakes region of the U.S., while Sigma is in the Southeast and Zeta is in the Far West.

We compiled data by conducting two focus groups of 3-4 PSTs and 10-13 instructor interviews at each site (except Zeta, where we conducted three interviews) and collected corresponding instructional materials from each instructor we interviewed. In the instructor interviews at each site, we included required mathematics, mathematics for teachers, mathematics education, and general education courses selected for potential algebra content.

Among other interview questions, we asked instructors which types of tools and technologies they used in a particular course and how they supported PSTs in making connections in algebra. Similarly, we asked PSTs in focus groups to identify required courses that incorporated opportunities to make connections or to use technology in learning algebra or learning to teach algebra. We asked PSTs explicitly about their required or shared experiences with connections and with technology.

Prior to considering the data for mentions of connections or technology, the *PTA* project team had coded data for algebraic content. In analyzing data, four researchers worked in pairs, reading the interview and focus group transcripts and discussing potential opportunities reported by instructors or PSTs.

For connections, the two researchers individually coded data sources based on the major four types of connections (e.g., connections within algebra, connections between algebra and mathematics) and met to make consensus on the coding. We then developed summary documents of each university, including tables of the number of opportunities and quotations in each course. We will analyze the quotations to document different types of opportunities that were reported (e.g., algebraic topics that PSTs were exposed, specific activities that PSTs engaged with, or/and opportunities to help PSTs learn to teach connections).

For tools and technology, the two researchers have so far only considered instructors' interviews and instructional materials. We captured types of tools or technologies mentioned by course instructors and PSTs, as well as details of the experiences the rationale (if any) given by the instructor detailing why (or why not) tools and technology were used (e.g., "dulls the mind" or "representations help students understand quantitative situations"). Based on previous research, we will analyze instructors' and PSTs' reports of technology use to understand why opportunities are or are not provided in particular mathematics or mathematics education courses, and to understand the types of experiences provided, whether the experiences are as a "practical expedient," or to "advance learning," or to provide opportunities for PSTs to think critically about choice and use of tools and technology by engaging with potential affordances and limitations (CBMS, 2001).

Results

For the purposes of this proposal, and due to space limitations, we focus on finding exemplars of *types* of experiences provided to PSTs by two of the five different programs (i.e., Beta and Kappa) and focus on experiences in Abstract Algebra, Linear Algebra, and Secondary Mathematics Methods courses. We are not evaluating the programs; rather, exploring strengths

and challenges of each program to understand what rich experiences across a program's offerings could look like, and to understand the challenges that arise.

Connections

Beta University. Linear Algebra instructor reported opportunities related to all four types of connections, while Abstract Algebra instructor provided examples of three types (except for the connections between algebra and non-mathematics) and Secondary Mathematics Methods instructor provided two types of connections (within algebra and between algebra and non-mathematics). To be specific, Linear Algebra instructor reported that he discussed the meaning of solving an equation connected to distributivity and associativity (within algebra), probability through Markov chains (between algebra and other math), population dynamics through modeling (between algebra and non-math), and connections between solving systems of linear equations and college algebra (e.g., identities, inverse). Abstract Algebra instructor reported that he emphasized common structures and themes behind different number systems, discussed connection between ring isomorphisms and graph morphissms in Discrete Mathematics course, and discussed the relationships between high school level division algorithm and machinery in the division algorithm. Secondary Mathematics Methods instructor focused on how PSTs made connections rather than how the instructor made them. The instructor said that PSTs made algebraic connections when they created lesson plans and participated in reading workshops.

Kappa University. Instructors of the three courses made different types of connections: Linear Algebra and Secondary Mathematics Methods instructors reported that they made the major types of connections except for connections between college and school algebra; and Abstract Algebra instructor reportedly provided opportunities except for connections between algebra and non-mathematics. Specifically, Linear Algebra instructor mentioned that PSTs studied how to solve systems of equations, connected them with the topics in the course, and learned how technology could best assist them. Abstract Algebra instructor reported PSTs' opportunities to learn about abstract proofs that are related to college algebra and the usefulness of number theory and set theory. Secondary Mathematics Methods instructor provided a specific activity (border problem) where PSTs discussed the meaning of the variable in context and generalized the situation by using both words and symbols, which provided them the opportunity to connect different representations and use geometry.

Tools and Technology

Beta University. The Abstract Algebra instructor reported using little technology in his course. He did provide experiences using instructional technologies to facilitate communication, however, by asking students in the course to collaboratively develop class agendas using GoogleDocs. For example, as part of the agenda, the instructor asked students to post questions on readings and add checkmarks to questions posted by classmates that they also had. Use of technology was extensive in Linear Algebra, as the instructor reported using Maple and targeted Java applets in weekly computer lab activities. When talking about the computer activities, the instructor used phrases like "they discover the concept" and "they develop intuitive understanding." The Secondary Mathematics Methods instructor reported focusing more on supporting PSTs in thinking about "the appropriate use of technology and helping their students [with] the appropriate use of technology" based on experiences that the PSTs have in their student teaching classrooms. For example the instructor reported discussing the possibility of the PSTs asking their students, "Here's a calculator. You need to tell me which five problems you want to use the calculator on and why." As a part of the course, the PSTs also keep a blog to communicate their experiences with each other and receive feedback on ideas they're trying out.

Kappa University. The Kappa Abstract Algebra instructor also reported using little technology in his course, but he also used instructional technologies to facilitate course communication. He used the Blackboard Learning Management System to communicate to students and asked students to write course or homework questions in the discussion section of Blackboard. He said that he also has recently begun using his iPad to record his voice and writing as he answers students' questions during office hours. He then posts those videos on Blackboard so that the student who asked the question "can go back and play it over and it's there for them" but also other students with similar questions can see his responses. The Linear Algebra instructor did not report using technology explicitly in his course, although he did provide access to Mathematica for his students. He did report using unsharpened pencils as physical tools in class to represent vectors and vector operations, and said he sometimes sees his students bring their own pencils to exams. The Secondary Mathematics Methods I course instructor reported using, "SMARTBoards, algebra tiles, pattern blocks, TI-83 calculators, Fathom, TinkerPlots, and GeoGebra." The instructor reported emphasizing "not using the technology and the resources for the sake of using them but making sure that there is a purpose and a reason behind why are we using this technology." The instructor reported many discussion about potential pedagogical uses of different tools and technology, especially focused on having students use their resources in mathematical investigations.

Discussion

Our preliminary results show different types of opportunities that PSTs were provided related to the learning of algebraic connections and the use of technology to learn and learn to teach algebra. There was a wide range of opportunities that instructors provided related to algebraic connections: some instructors provided lists of topics and ways that they made connections (e.g., Linear Algebra at Beta); others reported specific activities that engaged PSTs to make connections (e.g., Secondary Mathematics Methods at Kappa). At Beta University, mathematics instructors described how they emphasized different types of connections, while the mathematics education instructor focused on how PSTs made connections in his class. At Kappa University, instructors described connections among not only algebraic topics (e.g., systems of equations, variables), but also practices that can be used in different courses and grade levels (e.g., proofs, generalization), along with how technology can be used to make such connections (e.g., Linear Algebra instructor). We heard concerns from both mathematics and mathematics education instructors that technology could impede PSTs' learning. Some mathematics education instructors argued, to the contrary, that use of technology enabled PSTs to increase their understanding of algebra topics in ways that were not possible otherwise. At each university there was at least one opportunity for PSTs to think critically about their future educational use of technology, but experiences varied.

Our preliminary results on the other cases (i.e., Gamma, Sigma, Zeta) show patterns among the major types of connections and uses of technology in different courses, which we plan to share during the presentation. We will additionally provide detailed examples of how instructors provided PSTs with opportunities to make algebraic connections and use technology as recommended by policy documents (e.g., CCSSO, 1995; NCTM, 2012), along with different types of opportunities that can help other educators assess their own programs.

In our presentation, we plan to ask participants: From our preliminary analysis, what do you find surprising? What recommendations would you make for our analysis or what would you like

to see in published reports? One perspective on technology use in mathematics is that technology should mainly be used as a practical expedient to support applied mathematics projects. We plan to analyze our data specifically for opportunities for PSTs to engage in experiences that combine mathematical modeling, technology, and making connections. What would be interesting to you as results? How can we approach the analysis to make our results stronger?

Endnote

This study comes from the *Preparing to Teach Algebra* project, a collaborative project between groups at Michigan State (PI: Sharon Senk) and Purdue (co-PIs: Yukiko Maeda and Jill Newton) Universities. This research is supported by the National Science Foundation grant numbers DRL-1109256/1109239 and by the National Science Foundation, Spencer Foundation.

References

Conference Board of the Mathematical Sciences [CBMS]. (2001). *The mathematical education of teachers*. Providence RI and Washington DC: American Mathematical Society and Mathematical Association of America.

Conference Board of the Mathematical Sciences [CBMS]. (2012). *The mathematical education of teachers II*. Providence RI and Washington DC: American Mathematical Society and Mathematical Association of America.

Council of Chief State School Officers [CCSSO]. (1995). *Interstate Teacher Assessment and Support Consortium (InTASC): Model standards for beginning teacher licensing and development: A resource for state dialogue*. Washington, DC: Author.

National Board for Professional Teaching Standards [NBPTS]. (2010). *Mathematics standards.* Arlington, VA: Author.

National Council of Teachers of Mathematics [NCTM]. (2012). *NCATE/NCTM Program standards: Programs for initial preparation of mathematics teachers.* Retrieved October 12, 2012, from http://www.nctm.org/uploadedFiles/Math_Standards/NCTM%20NCATE%20Standards%20Revision%20and%20Math%20Content%20-%20Secondary.pdf

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common core state standards for mathematics.* Washington, DC: Authors.

Stein, M. K., Kaufman, J. H., Sherman, M., & Hillen, A. F. (2011). Algebra: A challenge at the crossroads of policy and practice. *Review of Educational Research, 81(*4), 453-492.

Teuscher, D., Dingman, S. W., Nevels, N. N., & Reys, B. J. (2008). Curriculum standards, course requirements, and mandated assessments for high school mathematics: A status report of state policies. *NCSM Journal*, 49.