Chapter 1
Educational Research on Mathematics Graduate Student Teaching Assistants: A Decade of Substantial Progress

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Not long ago nearly all materials and programs to help mathematics graduate students learn to teach were the product of the collective wisdom of experienced teachers of college mathematics. Although these products were often used to help graduate students learn about teaching-related issues, little research existed to inform the design of goals and approaches used in the products. This situation is beginning to change as the mathematics education research community works to amass information about graduate students' characteristics, experiences, and needs for professional development. This growing area of research borrows heavily from the more established base of research on K-12 teachers and their preparation. In this chapter we provide a tour of how this research area developed and the discipline-specific context in which that development occurred.

The systematic study of graduate students who are teaching undergraduate courses is a relatively new area of research in mathematics education. This area inherits a rich body of knowledge from work at K-12 levels that has formed the foundation of the education community's understanding of the processes of learning and teaching mathematics. This area also derives insights from research on graduate student instructors more generally. While some issues cut across disciplines, recent work acknowledges the influence of discipline-specific challenges (Austin, 2002; Gaff & Lambert, 1996) and has begun to identify differences among disciplines (Luo, Grady, & Bellows, 2001). To create the best learning opportunities for undergraduate students, we need to understand similarities and differences in the experiences and challenges faced by graduate students who live and work in various academic fields. Toward such discipline-specific understanding, researchers have documented features of the culture and community of mathematics and their influence on members of that community such as influences on women's career choices (Herzig, 2004) or influences on African American students (Ladson-Billings, 1997). The research reported in this issue represents some of the initial steps towards
understanding specifically how graduate students develop as teachers within the mathematics community.

**Context**

As was the case for earlier generations, the future of our nation’s economic success is often linked to our ability to produce a mathematically and technologically literate population. In the 1960s, much attention was paid to these issues in the name of competing in the Space Race. The reactions included changes to mathematics curricula and the introduction of new instructional practices. Subsequent decades saw a variety of initiatives designed to enhance the teaching and learning of K-12 mathematics. These efforts included the New Math movement of the 1970s as well as the introduction (and revision) of the National Council of Teachers of Mathematics Standards (NCTM, 1989, 2000). Initially, research and evaluation were primarily focused on student achievement with little attention paid to documenting and understanding how teachers implemented these new curricula and instructional practices. That situation has changed with the rapid expansion in K-12 mathematics education research during the last decades of the 20th century. In addition to illuminating teachers’ preparation and professional development needs specific to these instructional reforms, more recent developments have provided important insights into teachers’ practices that contribute to the educational research base. Current research in K-12 mathematics education reflects such findings by recognizing the complexity of teaching, the influences of culture and context on teachers’ practices, and the challenges of equipping teachers to enact effective instruction.

Today, the challenges the U.S. faces in the global and technological economy are portrayed as being at least as profound as challenges faced by past generations. The country’s ability to prosper has been characterized as relying in large part on the preparation we can provide to our children and young adults in mathematics and the sciences. Documents such as The World Is Flat (Friedman, 2005) and Rising Above the Gathering Storm (Augustine, 2005) make clear that the learning opportunities we provide for students must create a workforce of technologically, mathematically, and scientifically prepared citizens. Current government initiatives such as The No Child Left Behind Act and The American Competitiveness Initiative place much of the hope for meeting these challenges in the hands of teachers and those who prepare future teachers. The success of such initiatives rests in large part on the country’s ability to help students rise to the challenges of learning more and learning better in science, technology, engineering, and mathematics (STEM) fields.

A key component of any plan to improve student performance in the sciences and engineering is undergraduate mathematics. Mathematics courses serve both as a foundation to the study of STEM (and other) disciplines and also as gates through which students must pass in order to pursue careers in scientific fields (Ganter & Barker, 2004). In addition, such courses are the settings in which future teachers of mathematics receive much of their content preparation. Even students in non-STEM majors are required to fulfill general education requirements including mathematics and quantitative reasoning. Thus, undergraduate mathematics courses are part of the preparation of the vast majority of the country’s college educated citizens (Lutzer, Rodi, Kirkman, & Maxwell, 2007).

Major challenges to improving the country’s mathematical and scientific capacity arise from trends in student attrition from undergraduate STEM majors and courses. Contrary to folk wisdom, it appears that attrition is not simply a function of students’ inadequate preparation, aptitude, or lack of interest (Seymour & Hewitt, 1994, 1997). In fact, among students who leave mathematics and physical science majors, the most common complaint about their educational experience is poor teaching (stated by 90.2% of students who switched out of their majors). Moreover, the number who switch is substantial: approximately 50% of freshman mathematics, physical science, and engineering students change majors before graduation.

As is the case with K-12 mathematics education, there is also a history of concern about student achievement even for those who persist in mathematics at the undergraduate level. Research on undergraduate mathematics, which while mirroring the pre-collegiate level in many respects, has progressed at a different pace and in somewhat different ways. The 1980s brought a considerable increase in concerns about enrollment and retention rates as well as concerns about the depth and breadth of students’ understanding of college mathematics (Douglas, 1986; NSF, 1986, 1989; Steen, 1987). Concerns raised in early conferences and publications sparked activity in curricular and instructional change. This activity included, for example, the use of collaborative group work, modifications to traditional syllabi, and the introduction of various instructional technologies. As with earlier initiatives in K-12 mathematics education, toward the end of the 20th century much attention in undergraduate mathematics education was on measures of student achievement in courses that made use of new instructional materials and practices. For example, effects of incorporating computer activities into courses were investigated through comparisons of student outcomes from versions of the course where the activities were used to those that were taught without the technology (see, e.g., Bookman & Friedman, 1994). More recently, the focus has expanded to include examinations of the factors that shape the instruction that teachers provide for their students.

This expansion in focus from quantifying student achievement to seeking to understand how teachers’ use of particular materials and practices shapes students’ learning opportunities at the postsecondary level has emerged later than similar developments at the K-12 level. At the K-12 levels researchers
began examining teachers' practices several decades ago but to date there has been virtually no research conducted on the planning, instructing, or assessing practices (and the factors that shape them) of college teachers of mathematics (Smith, Speer, & Horvath, 2007). Only recently has the community of researchers who are examining the teaching and learning of undergraduate mathematics begun to uncover the complex factors that influence college teachers' practices and their students' learning, as well as beginning to identify elements of professional development that enable college mathematics teachers to provide effective instruction for their students.

The Role of MTAs in Undergraduate Education in the United States

Although faculty members teach many undergraduate students at masters- and doctoral-granting institutions, MTAs also often play central roles in the mathematics education of undergraduate students. MTAs' direct contact with current undergraduates at doctoral granting institutions is, however, rather difficult to quantify. Lutzer, Rodi, Kirkman, and Maxwell (2007) reported enrollment figures that indicate that 21% of mathematics and 17% of statistics undergraduate students at doctoral granting institutions are taught by MTAs. These figures represent a snapshot in time and do not answer the question of how many students take at least one course during their college careers with an MTA. Since these figures include developmental mathematics courses as well as advanced ones, if we assume that almost all college students at these institutions will take at least two courses (one mathematics course, possibly developmental, and one statistics course, or two mathematics courses), then we would estimate a 37% chance of having an MTA as an instructor at some time. This is noteworthy, given that most of these students will encounter an MTA early in their college mathematics careers, often in courses that serve as prerequisites to majors or program distribution requirements. Choices about continuing to study mathematics and feelings about the relevance of mathematics to other endeavors can be affected through these early experiences. Given that MTAs account for a sizeable proportion of contact hours with undergraduate mathematics students, we see a striking need to build research-based professional development programs, as has been done at the K-12 level.

The importance of teaching-related professional development for graduate students increases as we recognize that subsequent generations of postsecondary faculty will come from the current pools of graduate students, leading to long-term impacts on undergraduate education. The vast majority of future faculty members are educated in graduate programs at research-intensive universities. Currently, there are 127 such universities in the U.S. and they are the sites of professional preparation for approximately 80% of the graduate students in STEM disciplines (Gaff & Lambert, 1996). Many of these graduate students will go on to faculty positions at undergraduate institutions, dispersing among more than 4,000 research and comprehensive universities, liberal arts colleges, and community colleges. These faculty members will have very limited opportunities for teaching-related professional development during their careers (National Science Foundation, 1992). As a result, the professional development mathematics graduate students receive for their teaching responsibilities has the potential to influence the learning opportunities of vast numbers of college students.

Most universities provide general (i.e., not discipline-specific) teaching-related professional development opportunities for their graduate students. While the early history of K-12 teacher professional development had a similar focus on general pedagogical skills, discipline-specific efforts have become the dominant approach in recent decades. Evidence has accumulated that mathematics-specific knowledge plays a substantial role in shaping K-12 teachers' instructional practices and the learning opportunities they create for their students. Research in this area has demonstrated that teachers' knowledge of typical difficulties experienced by students while learning particular mathematics content as well as knowledge of especially illuminating examples and other mathematics-specific, teaching-specific knowledge are major factors that shape teachers' practices and their students' learning (Carpenter et al., 1989; Fennema et al., 1996). This focus on pedagogical content knowledge (Grossman, Wilson, & Shulman, 1989; Shulman, 1986) and on teaching-specific kinds of mathematical knowledge (e.g., Ball & Bass, 2000; Ball, Thames, & Phelps, 2008; Hill, Schilling, & Ball, 2004) has provided substantial evidence that the work of teaching demands more than just general teaching skills and knowledge of the content being taught. Learning from research at K-12 levels, we expect mathematics-specific issues to be relevant for graduate teaching assistants as well. Authors contributing to this volume have concentrated specifically on such issues.

Research on the Professional Development of MTAs

The Emergence of a Research Area

In the 1980s and early 1990s resources for MTA professional development became more widely available. While not research-based, these publications (e.g., Case, 1989, 1994; Friedberg et al., 2001a; Friedberg et al., 2001b) represented various groups' collective wisdom from practical experience about key issues in learning to teach postsecondary mathematics (e.g., parallel enculturation into the community of mathematicians and into the community of teachers, inexperience with the course paths taken by most of their students). The intended audience for these materials was staff who have responsibility
for the professional development of MTAs. Use of these (and other) materials/programs provided some of the context for the research-based inquiry, emerging in the late 1990s, into how MTAs learn to teach. For additional details of this development, see Speer, Gutmann, & Murphy (2005).

Contemporary with these publications were sessions at conferences of the American Mathematical Society (AMS) and the Mathematical Association of America (MAA) sponsored by the AMS-MAA Committee on Teaching Assistants and Part-Time Instructors. At these sessions, presenters addressed a variety of topics, but the tendency was to emphasize the administration of preparation and development programs for MTAs. As with the publications, most of these conference sessions relied on field experiences, rather than on a research knowledge base. Participants at these early conference sessions and authors of the time recognized and acknowledged the substantial need for research to inform program design.

One venue for such work appeared in 2002 with the creation of a Working Group for researchers who are interested in MTAs. Continuing to meet regularly since then (initially at conferences of the Psychology of Mathematics Education-North American (PME-NA) chapter and more recently at conferences of the Special Interest Group of the MAA on Research in Undergraduate Mathematics Education (SIGMAA on RUME)), this group has provided a forum for researchers to discuss and present their work. Operating under the belief that practitioners (those who run professional development programs for MTAs) have alternate professional communities (e.g., AMS, MAA, and the Professional and Organizational Development Network in Higher Education), the group was formed with the explicit intent of providing a community for people who are researchers. In addition to papers published proceedings, findings from research about MTAs have been disseminated at conferences and in publications such as the AMS's Research in Collegiate Mathematics Education series (1994-present).

The Nature of Research about MTAs

What began as thoughtful efforts to share experiences about teacher-training seminars for MTAs and to build new types of professional development, has grown into an effort to lay down a foundation of knowledge about who MTAs are and how they function and develop as professionals and to describe frameworks that connect theories of learning and teaching in ways that provide research-based guidance for the creation of new professional development curricula. Rapid progress in the field has been possible largely because of the emphasis placed on extending results from the established mathematics education literature on learning and teaching. As a consequence, research on MTAs has been less a process of inventing new models and methods and more one of adapting models and understandings to the particular world of MTAs.

One important goal of this work is to build on and constructively apply findings and theoretical perspectives developed in the K-12 mathematics education literature. For example, studies of teacher knowledge (Ball & Bass, 2000; Ball, Lubienski, & Mewborn, 2001; Calderhead, 1996; Fennema et al., 1996; Fennema & Franke, 1992; Hill, Rowan, & Ball, 2005; Hill, Schilling, & Ball, 2004; Mewborn, 2003) are being extended to investigations of MTAs, including investigations of pedagogical content knowledge (Grossman et al., 1989; Shulman, 1986) necessary for teaching. In general, the agenda of understanding elementary and secondary teaching experiences is being extended to include more detailed examinations of the challenges faced by MTAs as well as more extensive inquiry into the complexity of the context in which MTAs work.

In a broad sense, the research related to MTAs can be arranged into three categories:

- **Basic or theoretical research** is focused on advancing theory and methods to provide lenses that help us understand who MTAs are, how they think about what mathematics is and how it is learned, and how their communities help them define themselves and their profession. For examples, see Chapter 6 (Winter, DeLong, Wesley) and Chapter 8 (Kung and Speer) in this volume.

- **Documentary research** explores the lives of MTAs and MTA communities and provides stories and hard numbers. For examples, see Chapter 2 (Belnap and Allred), Chapter 3 (Hauk et al.), and Chapter 4 (Gutmann) in this volume.

- **Curricular research** examines the design and evaluation of professional development curricula and includes both the application of research findings to inform the planning and creating of new professional development experiences and the assessment of existing curricula. For an example, see Chapter 5 (Latulippe) in this volume.

These three types of research frequently overlap and work in this area often reflects more than one of these types—see, for example, Chapter 7 (Meel).

As is true in other areas of educational research, those who inquire into aspects of the MTA experience do so from a variety of theoretical perspectives and utilize a variety of research methods. Some, working within sociocultural traditions, examine characteristics and the nature of identities of beginning MTAs. Others seek to understand the structure and features of the communities in which MTAs participate. Researchers taking more cognitive approaches investigate MTAs’ knowledge and beliefs, including those related to student thinking and learning. Another area of current activity is curriculum development for MTA professional development and the adaptation of materials and programs from K-12 contexts for use with MTAs. In addition to these primarily qualitative research programs, quantitative researchers employ, for example,
large-scale survey research to document and examine the number of graduate students enrolled in institutions across the U.S. and collect information about their duties and the kinds of contacts they have with undergraduates.

The Future

If developments at the K-12 level are an indicator, we are only at the beginning of a complex process of understanding how the teaching and learning of undergraduate mathematics take place and how the contexts in which teaching and learning occur shape the learning opportunities of students. Topics that have been of interest in the K-12 world and that are apt to be important for work with MTAs include: how teachers learn to teach, how characteristics of teachers and their practices shape student learning, how culture and context shape everything, and how curriculum and methods are understood, adopted, and enacted. MTA researchers are beginning to make progress with some of these topics and we anticipate increasing cross-fertilization between the K-12 and postsecondary levels.

References


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The late Timothy Gutmann was an assistant professor in the Department of Mathematical Sciences at the University of New England. His research interests centered on mathematics graduate student teaching assistant communities and the types of interactions that help them learn about teaching, about how to value teaching, and about how to balance the demands of teaching and scholarship.

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