Preparing Secondary Mathematics Teachers

Initiating a Networked Improvement Community
Preface

For a long time, K–12 mathematics education in the United States has been unsatisfactory in stimulating students’ interest and fostering their achievement. A major contributing factor is the preparation of secondary teachers—those who teach mathematics to students in middle grades and high school.

By a variety of measures, the U.S. has a significant shortage of well-qualified secondary mathematics teachers. More than 1 in 6 secondary schools report “serious difficulties” in filling vacant mathematics teaching positions (Ingersoll & Perda, 2010). According to National Center for Educational Statistics (NCES) survey statistics (Keigher, 2010), 1 in 12 mathematics teachers leave the profession every year, with another 1 in 15 changing schools. The attrition rate is particularly high for beginning mathematics teachers, almost 1 in 7 leave teaching after their first year (Ingersoll, Merrill, & May, 2012).

The performance of U.S. students is disappointing. Less than 36% of eighth-grade students achieve proficiency on the National Assessment of Educational Progress (NCES, 2013). Only about 1 in 4 twelfth-graders are proficient in mathematics, and more than 1 in 3 do not possess a basic knowledge of mathematics, according to the latest National Assessment of Educational Progress (NCES, 2013). The ability to apply mathematics is measured by the Programme for International Student Assessment (PISA). For U.S. 15-year-olds, the PISA average continues to lag behind that for industrialized societies (Fleischman et al., 2010; Kelly et al., 2013; although some analyses are a little less gloomy; cf. Carnoy & Rothstein, 2013). In college, a large proportion of undergraduates take high-school level mathematics courses (Blair, Kirkman, & Maxwell, 2013). The implications are unsettling, given that mathematics is foundational to the national priority of improving participation in STEM—science, technology, engineering, and mathematics (President’s Council of Advisors on Science and Technology, 2010).

The situation is particularly acute for the most vulnerable students. National studies note that problems of teacher attrition and turnover are not uniformly distributed within districts, but tend to be concentrated by school (Ingersoll & May, 2010; Ingersoll & Perda, 2010), affecting a disproportionate number of high-poverty or minority schools. Similarly, California studies note that schools with high percentages of underprepared teachers (e.g., with emergency credentials or had not demonstrated mathematical competence) tend to be high-minority schools (Esch et al., 2005) or poorly performing schools (Bland et al., 2010).

The advent of the Common Core State Standards for Mathematics in 2010 augments the challenges already faced by secondary mathematics teachers. These standards, which have been adopted by most states across the nation, describe what students need to know and be able to do in order for success in college and careers. Their standards for mathematical practice rest on important processes and proficiencies with longstanding importance in mathematics education. These have been articulated in earlier calls for change such as the standards produced by the National Council of Teachers of Mathematics in 2000 and the National Research Council’s Adding It Up. But, of practicing secondary mathematics teachers, only about half report using
instructional practices and goals that would promote the Common Core (Banilower et al., 2013; Markow et al., 2013).

As a nation, we need well-prepared beginning secondary mathematics teachers who can immediately help their students achieve high standards, leading to college and career readiness in accordance with the Common Core State Standards for Mathematics. These beginning teachers need to successfully enter and remain in their profession, and continue their professional growth as effective secondary mathematics teachers. They need to serve as a catalyst for the continuing improvement of secondary mathematics education.

Research on teacher preparation is sparse, but what is known suggests that improving its quality can do much to improve its graduates’ instructional effectiveness and to retain them in their chosen profession. Preparing Teachers, a recent National Research Council report, states “there is relatively good evidence that mathematics preparation for prospective teachers provides insufficient coursework in mathematics as a discipline and mathematical pedagogy” (2010, p. 123). The Conference Board of the Mathematical Sciences report Mathematical Education of Teachers II notes, “Analyses of recent survey data find that in the first year of teaching, teachers with a mathematics baccalaureate, but little or no pedagogical preparation, left teaching at twice the rate of those with the same degree, but more comprehensive pedagogical preparation” (2012, p. 15). Such preparation tended to include a full semester of practice teaching (Ingersoll, Merrill, & May, 2012, p. 33).

Despite well-publicized alternative routes to certification, the overwhelming majority of teachers are still prepared in postsecondary institution undergraduate programs that include mathematics courses, methods courses, and student teaching under the supervision of a mentor teacher (USDE, 2013). Many of these institutions are members of the Association of Public and Land-grant Universities (APLU). APLU is a research and advocacy organization of public research universities, land-grant institutions, and state university systems with member campuses in all 50 states, U.S. territories, and the District of Columbia. Its members include many distinguished universities and conduct nearly two-thirds of all federally-funded academic research, consistent with the commitment of land-grant universities to serving the needs of the states and the nation.

APLU institutions prepare 40% of the new secondary mathematics and science teachers who graduate each year. In 2008, this commitment to teacher preparation, together with increased national concern about STEM education, led to APLU’s formation of the Science and Mathematics Teacher Imperative. Its goal is to assist public universities to increase the number and improve the quality and diversity of science and mathematics teachers they prepare. The advent of the Common Core State Standards for Mathematics accentuated the need for a project focused on secondary mathematics teacher preparation, leading to the formation of the Mathematics Teacher Education Partnership in 2010.

The Partnership consists of teams of institutions that are collaborating on improving secondary mathematics teacher preparation. Each team is headed by an APLU member institution, and includes at least one other partner engaged in secondary mathematics teacher preparation and at least one K–12 partner. In order to be accepted into the partnership, teams needed to demonstrate their commitment to transforming secondary mathematics teacher preparation, including
collaboration across team institutions; active involvement of stakeholders, including mathematicians, mathematics educators, and K-12 personnel; and institutional support for the effort. In February 2012, 38 teams were accepted into the partnership—including 87 school systems, 68 universities, and 9 community colleges, as depicted in the map below. The 30 partnership states are shown in blue, and stars indicate the locations of the lead institutions of the 38 teams.

Each team includes a range of stakeholders who are actively involved in secondary mathematics teacher preparation. Among the roles played by team members are: instructing candidates in mathematics content courses as well as in courses addressing mathematics teaching methods; organizing and supervising candidates in their field experiences and serving as K–12 mentors for those field experiences; and providing other kinds of support for teacher candidates and K–12 mentors.

Collectively, these teams have a vast array of practical wisdom about teacher preparation. They include teachers, coaches, and state and district education personnel. They draw on the experiences of mathematicians, mathematics teacher educators, and others involved in earlier projects to improve teacher education. The chapters in this monograph organize this collective knowledge as preparation for the next phase of the Partnership’s work. They focus and analyze research relevant to teacher preparation and responses to a survey of its teams conducted by the Partnership, and organize this information to promote collective communication and action.

This monograph is thus a progress report of work on a complex problem. It is intended to provide insights that can guide the continued improvement of secondary mathematics teacher preparation by:

• Mathematicians, statisticians, mathematics teacher educators, and other members of institutions of higher education involved in secondary mathematics teacher preparation—
both those involved with the Partnership, and those beyond it. At the risk of oversimplification, this report will refer to this audience as “mathematicians” and “mathematics educators.”

- Teachers, administrators, and other personnel from K–12 institutions involved with secondary mathematics teacher preparation—both those involved with the Partnership, and those beyond it. In this report, they will often be called “mentor teachers” and “district personnel.”

- Personnel from state departments of education and others involved in setting policy related to secondary mathematics teacher preparation.

- Personnel from other projects and initiatives related to the improvement of secondary mathematics teacher preparation.

**Terminology.** Terms in education sometimes have different meanings. This report uses the following terminology:

*Secondary teacher preparation programs.* Programs preparing teachers for grades 6 through 12. These programs may focus on middle school level (which in some states may include grade 5), at the high school level, or across the secondary school grades.

*Teacher candidate.* Terms often used with similar meanings are “prospective teacher” or “preservice teacher.” Someone who is in the process of being educated as a teacher but who is not yet licensed or certified as a teacher.

*Field experiences.* K–12 school-based experiences. Field experiences that occur early in preparation programs often include classroom observation or tutoring in an after-school program. Later experiences may be lesson planning and teaching small groups of students or single lessons, followed by teaching under the guidance of an experienced teacher.

*Student teaching.* Synonyms are “practice teaching” and “internship.” Its duration may range from 8 weeks to a year.

*Clinical experiences.* A subset of field experiences in which a prospective teacher takes on instructional roles such as lesson planning, teaching classes, and student teaching under the guidance of one or more experienced teachers.

*Mentor teacher.* A K–12 teacher who provides guidance to prospective teachers during their clinical experiences. Synonyms include cooperating, practicing, or expert teacher.

*Induction.* School-based experiences designed for newly certified teachers.

*Common Core State Standards (CCSS).* A set of academic standards in mathematics and English language arts/literacy (ELA) developed by the National Governors’ Association
and the Council of Chief State School Officers. This document primarily refers to the standards for mathematics.

References


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Introduction

A Networked Improvement Community for Secondary Mathematics Teacher Preparation

W. Gary Martin
Auburn University

Howard Gobstein
Association of Public and Land-grant Universities

The goal of the Mathematics Teacher Education Partnership (MTE-Partnership) is to transform secondary mathematics teacher preparation in order to ensure teacher candidates can promote mathematical excellence in their future students in alignment with the Common Core State Standards for Mathematics and other standards promoting college- and career-readiness. This goal is operationalized in a two-part aim:

1. Using benchmarks developed by the Partnership, institutions in the Partnership will document that their graduates are prepared to provide the instruction needed to help their students achieve mathematical excellence.

2. MTE-Partnership institutions will increase their number of graduating secondary mathematics teachers by a target percentage with an emphasis on increasing diversity.

While the Partnership is united in this aim, it is diverse in several ways. Team institutions include large public universities, smaller colleges and community colleges, local K–12 school districts, and state departments of education. These institutions operate in a variety of contexts: rural, suburban, and urban; high-needs and advantaged; racially diverse or more homogeneous; large numbers of English Language Learners or fewer. Their preparation programs may take varying forms, such as traditional undergraduate degree programs, fifth-year programs, or master’s certification programs, and may address different grade bands. Individuals on these teams come from different disciplinary backgrounds, have had varying experiences, and may have very different job demands placed on them. Each team member has a different view of the situation and each has a different kind of contribution to make. The MTE-Partnership thus faced a major challenge: How to harness the power of this network of diverse institutions and people by organizing them in a structure that uses their strengths to build meaningful improvement in secondary mathematics teacher preparation.

The “Networked Improvement Community” (NIC) structure developed and used by the Carnegie Foundation for the Advancement of Teaching (Bryk et al., 2011) has been used successfully in improving outcomes in developmental mathematics courses for a network of community colleges located in different states (Van Campen, Sowers, & Strother, 2013). For this and other reasons described below, the NIC structure was adopted by the Partnership as the organizational structure best suited to achieving its goals. As described by the Carnegie Foundation, a NIC has four essential characteristics. It is:

- focused on a well specified common aim that alleviates a problem.
• *guided* by a deep understanding of the problem and the system that produces it.
• *disciplined* by a focus on interventions with measurable outcomes.
• *networked* to accelerate the development, testing, and refinement of interventions and their effective integration into varied educational contexts.

NICs are designed to marry precepts of design science with precepts of networked improvement, so that the improvement cycles can be carried out across a range of contexts (Bryk et al., 2011). Thus, partners are mobilized to work in a parallel and coordinated manner to address critical subproblems hindering the transformation of mathematics teacher preparation. The NIC’s emphasis on rapidly prototyping, testing, and refining strategies for improvement is designed to create timely solutions to important problems and directly supports the Partnership’s objectives. Moreover, because the partnerships serve a range of populations, the NIC’s networked nature means that interventions are tested in a variety of contexts. Rather than trying to “control” variation, as is common in educational research, variation is embraced in order to study how interventions might be responsive to differing conditions under which they might be used. With this structure, local efforts can be linked to form large-scale understandings.

The NIC structure used in educational reform (e.g., Dolle et al., 2013) adapts ideas and organizational structures used in health care reform (e.g., Plsek, 2001). These organizational structures are designed to change a complex adaptive system, that is, one with many elements which is adaptive rather than mechanical in the sense that its elements have the ability to respond to stimuli in different and sometimes unpredictable ways that change the context for other elements of the system (Plsek, 2001). Examples of such systems range from antibiotic-resistant bacteria, a colony of social insects, or almost any collection of human beings (e.g., the U.S. health care system). Iteration is central to this design of the organizational structures used to improve such systems: beginning with a shared hypothesis about the problem structure that affords rapid-cycle experimentation on subproblems in priority areas, measuring and comparing experimental outcomes, spreading successful innovations, refining the hypothesis, and recalibrating priorities.

The following sections outline key aspects of the MTE-Partnership that embody the four essential characteristics of NICs.

**Understanding the system**
The Partnership makes the hypothesis that teacher preparation is an outcome of a complex adaptive system. Within each team, the parts of this system typically include a university—both a mathematics department and a teacher preparation “unit” (which may be a department—and a school district, as well as other institutions. The system is adaptive in that its outcomes change in response to changes in its elements (e.g., changes in school district or mathematics department policy) and external changes (e.g., state mandates for teacher certification). The problem is to improve selected outcomes of teacher preparation programs—the quality and quantity of graduates—by changing elements of the system.

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1 Among the outcomes is the surgery checklist described by Atul Gawande, e.g., Gawande, 2010; Haynes et al., 2009.
In devising a NIC, it is critical that the system being improved be well understood. The MTE-Partnership’s attempts to understand the system of secondary mathematics teacher preparation pre-dated the decision to form a NIC, but subsequently formed an important foundation in the formation of the NIC. *Guiding Principles for Secondary Mathematics Teacher Preparation Programs*, which describes a shared vision to be refined by the Partnership and others involved in preparing secondary mathematics teachers, was publicly released following the first Partnership conference. This report built on extensive feedback from the Partnership teams before, during, and after the conference, and is included in Appendix A. Updated versions are available at [http://mte-partnership.org](http://mte-partnership.org).

These guiding principles provide a framework on which subsequent analysis and activity were built. They are represented below as a map of the secondary mathematics teacher preparation system. In this depiction, partnerships are seen as foundational to the enterprise; unless key players within the university (including departments and colleges of mathematics and education) and K–12 partner districts have shared vision and goals, their teacher preparation programs will not be successful. Pre-program structures must be in place to attract high-quality candidates. Within the programs, focus must be placed on developing mathematical knowledge (including mathematical practices) needed to teach secondary mathematics as well as on developing educational practices likely to support student success. Clinical experiences connect candidates’ university experiences to the world of K–12 schools. Finally, as graduates of these programs begin their careers, mentoring is required to ensure their continued development as teachers of mathematics.
Understanding the problem
In order to improve, problems facing the system must be understood. Identification of priority areas for initial focus by the Partnership began at the first conference and continued through Summer 2012. Multiple elements of this system (processes, cultural norms, and structures) were identified as affecting the quality and quantity of teacher graduates. Highest-priority factors include shared (or unshared) vision among stakeholders (including mathematicians, teacher educators, and school district personnel), mathematical and pedagogical preparation of teacher candidates, recruitment of teacher candidates, retention of teacher candidates, and the mentor teachers who guide practice teaching experiences. These factors are displayed in a “fishbone diagram” in which arrows indicate pathways by which the factors affect outcomes. Note that additional factors may be considered at a later point in time.

A working group for each area was established in August 2012, involving 130 representatives from 27 Partnership teams. These working groups focused on better understanding their respective areas, culminating in a series of white papers that explicated the research in each area for discussion at the second annual conference. Revised versions of these white papers were the genesis of the first four chapters in this monograph. The fifth chapter focuses on common measures for evaluating progress.

Partnership driver diagram
“Driver diagrams” are primary tools for analyzing problems and explicating ideas for specific work to address them. As described by the Carnegie Foundation, “primary drivers are the major causal explanations hypothesized to produce currently observed results. Secondary drivers, in contrast, are interventions in the system aimed at advancing improvement toward targets” (Bryk et al., 2011). Note that driver diagrams are not intended to be comprehensive; drivers are prioritized to focus on interventions that have the potential to “move the needle” towards the established aim.
The diagram below shows four primary drivers of immediate importance in attaining the Partnership’s aim, along with preliminary secondary drivers that might address these primary drivers. The primary drivers reflect the four priority areas of action identified in the first phase of the project, and the secondary drivers reflect the working groups’ efforts to better describe possible solution pathways. These drivers were subsequently refined during the 2013 MTE-Partnership Conference and in post-conference work.

Driver Diagram for Initial phase of Partnership.

I. Shared vision of preparation
Create shared understanding and commitment among mathematicians, mathematics educators, and K–12 partners.

II. Mathematical preparation
Develop teacher candidates’ knowledge of mathematics necessary for teaching.

III. Clinical preparation
Improve teacher candidates’ clinical experiences by partnerships with mentor teachers and other stakeholders.

IV. Recruitment and retention
Attract, retain, and graduate an adequate supply of teachers.

A. Stakeholder involvement.
B. Institutional support.
C. Focus on student learning.
D. Building a learning mindset.
E. Tools for collaboration.

F. Mathematical Education of Teachers II recommendations.
G. Ways of knowing and learning.
H. Coherence of courses.
I. Assessment of knowledge.

J. Mentorship.
K. Partnerships.
L. Evaluation.

M. Recruitment to program.
N. Retention in program.
O. Retention in profession.

Developing an action agenda
Each of the first four chapters focuses on one of the primary drivers shown above. Based on the draft white papers prepared prior to the 2013 Partnership Conference and reflecting feedback provided at the conference, these chapters provide a literature review, secondary and tertiary drivers that may promote change in the primary drivers, and discussion of measures that might be used to track progress. Each ends with an agenda for addressing the problem area in the form of potential interventions (Research Action Clusters) that might be launched to promote change in the drivers.

Measuring progress
One of the Carnegie Foundation’s Core Principles of Improvement states, “We cannot improve at scale what we cannot measure.” Use of shared measures to track progress towards shared aims and benchmarks is considered central to the effective functioning of a NIC. Some of the measures that need to be identified or developed for use by the MTE-Partnership include:
• Global measures of candidate quality are needed, consistent with the aim of defining Partnership benchmarks.
• Given the difficulty of developing global measures, available proxy measures are needed as indicators of candidate quality in the interim.
• More specific measures will be needed to track progress in particular interventions developed by the RACs.
• Process measures of program quality will help to establish that programs are making overall progress.

Additional discussion of these issues is included in the chapter “Measuring Quality in Secondary Mathematics Teacher Preparation.”

References


