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**Developing Effective Mathematics Teachers through National Science Foundation
Funded Math and Science Partnership Program Grants¹**

Guest Editors

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Every year the National Science Foundation (NSF) gathers together leadership teams of funded Math and Science Partnership programs (MSP) at a Learning Network Conference in Washington, D.C. The purpose of the annual conference is to bring together teams of MSP leaders who represent institution higher education (IHE) faculty from STEM disciplines, IHE education faculty, school partners, and project evaluators, to give them an opportunity to learn across projects, and provide opportunities for individual projects to reflect on their progress. For the last two years, 2011 and 2012, we were part of the conference's organizing committee. During the two-day conference, project teams were invited to articulate their theories of action for preparing teachers to be effective STEM teachers and to describe in broad strokes or in fine grain detail what was happening within their projects' professional development opportunities. Projects also had the opportunity to share within a public forum the preliminary, incomplete, or final results emerging from projects' evaluations or research efforts aiming to determine whether the MSP projects were deepening teachers' content and pedagogical knowledge, changing teachers' practices, and, ultimately, positively impacting students' success.

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While the Learning Network Conferences are intended to be for leaders within the MSP community, what MSPs are learning about STEM teaching and learning and professional development are worth sharing to a wider community.. Thus, as follow up to 2012 Learning Network Conference, we proposed to help MSP teams publish articles focused on mathematics teaching and learning accessible to a community broader than other MSP projects. Dr. Bharath Sriraman, editor of *The Mathematics Enthusiast*, generously offered us the opportunity to publish this special issue.

We approach the task of guest editors as empathetic solicitors and reviewers of scholarship associated with MSP projects. We are leaders, ourselves, for multiple MSP projects, and have been since 2004, first for a middle school mathematics project (*Math in the Middle Institute Partnership*, <http://scimath.unl.edu/MIM/>) and now for a K-12 mathematics project (*NebraskaMATH*, <http://scimath.unl.edu/nebraskamath/index.php>); Smith is also a leader on a Research, Evaluation, and Technical Assistance (RETA) project (*Data Connections*, <http://scimath.unl.edu/dataconnections/index.php>). We understand the time-consuming nature and inherent challenges of trying to create meaningful professional development with teams of interdisciplinary IHE faculty, and partner with school districts, to offer professional development and study its impact on teachers and their students in the dynamic life of real districts, schools, and classrooms. We have experienced the learning of teachers and their students to be neither linear nor quick, therefore, we understand that studying STEM teaching and learning is messy, long term, and anything but straightforward. We understand that, for the most part, it is the same MSP leaders who are offering professional development as who are trying to study its effectiveness and that frequently the days are not long enough to do both simultaneously.

Thus, we find MSP projects with their own rhythm and life, waxing and waning their research efforts in concert with their professional development offerings, with one or the other receiving more attention at any given point in time. All MSP project leaders must balance a set of teaching and research priorities in ways that never quite feel satisfactory. These are priorities and tensions that we, indeed, understand from the inside.

We sent out a call for articles to the 2012 Learning Network Conference participants following the conference, and a motivated, hard working group of authors, who double as leaders for mathematics focused MSP projects, responded, some of whom are publishing their scholarship for the first time in this special issue. They have taken their 2012 conference presentation proposals and presentations focused on the theme of effective STEM teaching and created manuscripts. Peers reviewed each manuscript and offered authors constructive feedback. The authors have responded to feedback from those reviewers as well as worked with feedback from us, as the guest editors of this special issue.

What has resulted is a collection of seven thoughtful articles representing MSP projects from across the United States, all with the common goal of aiming to improve mathematics teaching and learning at various points in the K-12 spectrum of schooling. Across all seven articles, the authors see essentially the same challenge and in some sense, the same solution—how best to build mathematics teachers' capacities by increasing and deepening teachers' mathematical and pedagogical knowledge and, in turn, impact student learning. However, each MSP project has its own ideas about how best to leverage change in teacher knowledge and practice, and, ultimately, student learning. Each project is at a different stage in the process, from programs in their infancy to ones that are more mature.

Each project appears to be having success, but how individual programs define success and the degree to which the individual projects have rigorous research designs and data to support their assertions of success varies greatly.

Some of the seven articles have the look and feel of research manuscripts. Others do not. Nevertheless, the authors of each of these seven articles, as leaders of MSP projects, each have a worthwhile story to tell. We have organized them by their longevity as NSF funded projects. The projects include “young” ones that are several years into their project and have had a first cohort of teachers experience their professional development. These projects are positioned to be able to offer a rationale and detailed description of the content of their professional development and anecdotes from their own and their participants’ experiences. Other projects are more “mature” and have been in the MSP business for nearly a decade. These projects have a wealth of wisdom and insight to offer through the results of quantitative analyses of longitudinal data on teachers’ and students’ learning or findings from qualitative data on how teachers and students seem to learn and promising vehicles of teacher change.

We begin with the article by Teixidor-i-Bigas, Schliemann, and Carraher, of the MSP project at Tufts University and TERC, who created *The Poincaré Institute for Mathematics Education* in 2010. The project is an interdisciplinary partnership among faculty in mathematics, physics, education, and nine school districts in three states with the overarching goal of improving the teaching and learning of mathematics in middle schools. Interestingly, this project has chosen to focus their professional development on the topic of functions as a common mathematical topic in the elementary, middle, and high school curricula. Functions also serve as an interdisciplinary connection between mathematics

and physics and provide a “common ground” for three graduate level courses designed to support the mathematical and pedagogical learning of middle school teachers.

The article features a detailed description of the three courses that make up *The Poincaré Institute for Mathematics Education*, designed to help teachers learn the mathematical content they need to know to be able to teach the concept of functions to their students and develop and plan meaningful activities that integrate mathematics and science which they can use with their students. The first of three cohorts of teachers recently completed the program. Teixidor-i-Bigas, Schliemann, and Carraher note within the article how they have continually revised the details of their course offerings based on continual assessment of the learning of the teachers. The authors are just in the beginning stages of assessing the impact of their program based an evaluation of teachers’ performance on course assignments, teachers’ and their students’ level of mastery of mathematical content on project designed assessments, videos of teachers’ classroom practice, and students’ performance on state mandated math assessments.

The next article is co-authored by Kinzer, Bradley, and Morandi, a team of mathematics educators, research mathematicians and public school leaders, who lead a MSP project, the *Mathematically Connected Communities Leadership Institute for Teachers* (LIFT) at New Mexico State University. This K-12 project is similar to *the Poincaré Institute for Mathematics Education* project in that the professional development focuses on strengthening mathematical and pedagogical knowledge. However, the teacher leaders who participate work closely together for two years and have the opportunity to earn a masters degree in teaching mathematics. Teacher leader participants take pairs of courses,

designed and taught by teams of mathematicians and educators to offer parallel learning opportunities in both content and pedagogy.

A unique feature of the LIFT project, as Kinzer, Bradley, and Morandi describe, is the use of descriptive feedback in multiple forms as formative assessment to improve instruction and support learning at every level of teaching and learning involved within both the LIFT project and K-12 classrooms of mathematics teacher leaders. The authors offer specific examples of how instructors, teacher leaders and their peers all give one another feedback in a variety of forms in an effort to support learning from experience in a collaborative and constructive manner. The authors describe how the feedback has influenced changes in the teaching and learning practices of all stakeholders.

The third article in this special issue is by Lewis, Fischman, Riggs, and Wasserman, and features the *Noether Project*, a MSP project that uses an intensive two week summer institute followed by academic year lesson study teams, as the major organizational structure for providing learning opportunities for teachers of grades four, five and six across multiple school sites to develop mathematical and pedagogical content knowledge. The focus of this article is on describing the three lesson study teams' experiences, and analyzing similarities and differences across the experiences. In doing so, Lewis et al. tell a story from the experiences of each team while using each team's experience to address one of the following questions: what teachers are learning from lesson study groups, why it appears that teachers learn from lesson study experiences, and how the learning of teachers within lesson study groups seems to happen.

Lewis et al. tell their stories in the article based on notes taken by the lesson study group facilitators during the group meetings. They also draw on examples of student work

discussed within the lesson study group meetings as well as piece together and analyze conversations within lesson study group team meetings based on notes taken during the meetings and snippets of transcripts made from periodic video recordings of lesson study team meetings. The result is a set of interesting stories of teachers learning together about teaching, children, and mathematics from practice. The authors are hopeful that the district will, over time, assume leadership responsibility for the lesson study teams and that long after NSF funding, the lesson study teams will exist as a sustainable model of teacher professional development.

The fourth article, by Gningue, Peach, and Schroder, is about the *Mathematics Teacher Transformation Institutes* (MTTI) for middle and high school teachers in New York City, led by an interdisciplinary team of mathematicians and education faculty from Lehman College working with school district leaders. Like the other projects in this special issue, the professional development offered to teachers includes challenging mathematical content. However, this project adds an additional component of action research, offered in a two-part course series. Through action research, MTTI teacher leaders study the effectiveness of their own teaching practices by gathering data and systematically examining the learning of their students.

This is the first article in the special issue to describe the project's intentional research efforts to better understand participants' mathematical and pedagogical learning, any resulting impact on classroom practice, and the degree to which the participants' students are showing evidence of increasing their mathematical engagement. Gningue, Peach, and Schroder describe data collection instruments being used to assess impact as well as some of their preliminary findings.

The fifth, sixth, and seventh articles in this special issue represent mature MSP projects which have benefitted from long-term NSF funding and, thus, have been providing professional development to teachers and studying impact on teacher and student learning for a number of years. They are also well-documented projects so all of their stories of teacher learning in their articles are supported by data analyses that offer insights into both how and what teachers are learning about mathematical content and mathematical practices or habits of mind.

The MSP project based at Virginia Commonwealth is featured in the fifth article, by Whitenack and Ellington. The authors work from the premise that the K-8 teachers in their project have acquired content knowledge as part of their participation in a Mathematics Specialist Program. Whitenack and Ellington focus on the description and analysis of a single class discussion to better understand how teachers may have developed new mathematical understanding as participants in their program. In the article, the authors carefully describe tasks given to teachers, the intentions underlying the task, and how teachers responded. This article helps to further understanding about the process of teacher learning.

The sixth article, by Saylor, Apaza, Kapust, Roth, Carroll, Tambe, and St. John, features *Promoting Reflective Inquiry in Mathematics Education* (Project PRIME), a MSP project based at Black Hills State University that has been offering various forms of professional development to strengthen K-12 practicing teachers mathematical and pedagogical content knowledge for the last nine years. This project has extensive longitudinal data that hint at positive impacts on changing classroom practice and provide some evidence of closing the achievement gap for disadvantaged students. What is

particularly interesting about this project, however, is that the professional development offered to teachers over the years has been varied and complex, making connecting changes in practice or student learning to particular forms of professional development quite difficult. This project is the only one in the series with longitudinal data. However, the complexity of the features of Project PRIME, as a whole, while being rich in what has been offered to teachers, limits the causality claims about the changes in practice and improvement in student learning.

The final article in this special issue, by Matsuura, Sword, Piecham, Stevens, and Cuoco, represents the longstanding work of an interdisciplinary team of mathematicians, mathematics educators and classroom teachers, who have been working for nearly two decades on the notion of mathematical habits of mind. Their MSP, *Focus on Mathematics* was funded first as an institute, and later as a phase II grant. The article features an operational definition of habits of mind and a discussion of efforts to develop and use a survey instrument and observation protocol to measure the nature and degree of teachers' uses of mathematical habits of mind in teaching practice. The article describes and then compares and contrasts three teachers' uses of mathematical habits of minds as both learners and teachers of mathematics.

Following the seventh article, Marilyn Strutchens and Gary Martin more information about MSP context as well as a brief commentary on the articles themselves. Strutchens and Martin first talk about their own MSP, TEAM-Math, focusing on the power of the learning communities that have developed over time. Strutchens and Martin relate their work on TEAM-Math to the work of the seven MSPs featured here in this special issue, and highlight commonalities and differences across projects. All of the projects have the

ultimate goal of increasing levels of student success, and all are attempting to do so through teacher professional development. Within that broad vision, each MSP project has taken a unique approach to developing effective mathematics teachers and all are seeing positive results in terms of teachers' learning and students' achievement.