

Partnerships, Policy, and Educational Change: The Role of Mathematics and Science in K-16 Reform

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Concerns about American competitiveness and innovation have led to increasing scrutiny of science, technical, engineering, and mathematics (STEM) education. Leaders in the higher education, business, and legislative communities have all issued calls for expanded opportunities and training in STEM fields to improve the skills of the U.S. workforce. Older arguments for change, including stronger alignment of K-12 and higher education curriculum and the overall reform of teacher preparation, are incorporated within these recent calls, and share similar policy and implementation challenges. This analysis identifies the National Science Foundation Math Science Partnerships program as an emblem of the challenges of engaging K-12 and higher education in major reform efforts within a dynamic policy environment.

Keywords: STEM; Faculty; Higher Education; Partnership; Policy

Concerns about American competitiveness and innovation have led to increasing scrutiny of science, technical, engineering, and mathematics (STEM) education. Leaders in the higher education, business, and legislative communities have all issued calls for expanded opportunities and training in STEM fields to improve the skills of the U.S. workforce. Notions of economic competition and decline have fueled rhetoric and action affecting STEM fields in the United States during the early years of the 21st century. Numerous policy actions, legislation, and reporting have identified the critical role of STEM research and teaching in advancing U.S. competitiveness.

The current focus on the shortages of qualified STEM graduates entering the workforce echoes that of the Sputnik situation half a century earlier. The range of these reports and actions involves educational and economic lobbying organizations, state and federal governments and their lobbying associations, as well as individual critiques (Córdova, 2006). In 2006, such a vast number of these publications had been issued that one commentator felt safe in designating it “the year of the report” (Simpson, 2006).

Whether the United States actually is falling behind in preparing qualified workers in STEM fields (and in preparing students in K-12 classrooms) belongs to a larger policy debate and historical and economical analysis. This analysis will focus on the role of the National Science Foundation Math Science Partnerships program (NSF-MSP) as an example of a major policy solution designed to respond to these conditions, and to aspects of school reform, such as improved alignment between K-12 and higher education, and teacher preparation and professional development. The experiences of the NSF-MSPs provide a rich example of the challenges and limitations inherent in engaging and funding partnerships.

Such issues as program sustainability, the gulf between faculty and organizational culture in the K-12 and postsecondary sectors, and the variability of policy and political leadership each present challenges to successful partnership. NSF-MSPs engage STEM faculty and administrators, as well as education faculty and K-12 teachers and school and system administrative staff in their work.

The Climate

For several years, numerous stakeholders have issued reports on American competitiveness, each emphasizing different aspects of the role of higher education. These voices range from the National Academy of Sciences and the Business Higher Education Forum (2005, 2007) to the National Center for Education and the Economy (2006) and the U. S. Department of Education (2006).

These reports differ in emphasis and were directed to different audiences, but shared some common themes: that the production of STEM graduates in the U.S. has declined sharply, that other nations are preparing technical professionals at a pace faster than we have and are increasing their capacity to compete with the United States, and that the United States has fallen far behind in innovation, research, and production. A recent report from the Business Higher Education Forum calls for coordinated efforts to recruit, train, and maintain highly qualified teachers in STEM subject areas, but does not discuss partnership efforts (Business Higher Education Forum, 2007). Underlying these reports is an assumption that higher education bears major responsibility for these conditions and is central the solution.

Calls to reform STEM education follow prior actions related to school reform and attempts to transform teacher preparation and professional development. Both the 1998 reauthorization of the Higher Education Act (HEA) and the 2002 reauthorization of the Elementary and Secondary Education Act (commonly known as No Child Left Behind) require greater accountability from K-12 and higher education. Title II of HEA requires colleges and universities to demonstrate that their preparation of K-12 teachers met acceptable levels. NCLB obligates states and districts to provide “highly qualified teachers” in K-12 classrooms and provides sanctions for districts and states that fail to meet federal standards.

The reauthorizations represented an increased federal role in state and institutional policy-making and had strong bipartisan support. The 1998 HEA reauthorization was passed by a Republican-majority Congress and signed by a Democratic president; one of the bill’s strongest supporters was a Democratic senator, Jeff Bingaman of New Mexico. The 2002 reauthorization of the Elementary and Secondary Education Act, named “No Child Left Behind” for its sweeping scope of involvement in testing, tutoring, and accountability requirements, was passed by a split Congress and signed by a Republican president.

These federal activities were accompanied by similar actions in the states, including development of several statewide K-16 initiatives in the late 1990s and early years of the 21st century. Student achievement in elementary and secondary grades was showing disappointing results, supported by data from the so-called Nation’s Report Card, the National Assessment of Educational Progress and from state-level tests. Data from international assessments have also provided discouraging news. (U. S. Department of Education, 2007.)

Additional concerns cited in these reports and in other forums include conditions of the teaching workforce and declining numbers of teachers qualified to teach mathematics and science in grades K-12 (American Council on Education, 1999 & 2002). Factors affecting attrition in the teaching workforce include working conditions, curricular and testing pressures, and teaching out-of-field. The requirement for a “highly qualified” teacher in each classroom was at odds both with the current workforce production demands and with other facets of the legislation, as well as with resource shortages in states such as Florida.

In 2002, the National Science Foundation established the Math Science Partnership (MSP) initiative that seeks both to develop partnerships between the K-12 and higher education communities and to provide substantial and rigorous evidence on the reform work conducted by the projects. The NSF MSPs are five-year projects that are intended to embody five key features: partnership-driven; evidence-based design; teacher quality, quantity and diversity; institutional change and sustainability; and challenging courses and curricula. (National Science Foundation, 2005). The partnerships directly engage STEM faculty (with education faculty playing a supporting role) in partnership activities with schools and higher education institutions (IHEs) involved in the partnerships.

There are three types of NSF-MSPs—comprehensive, targeted, and institute—and a wide variety of partnership models. Targeted MSPs involve a single curricular area (mathematics or science) and usually focus on a single K-12 segment, such as middle school; they may involve one or several IHEs and one or several school districts. Comprehensive MSPs involve a number of school districts and multiple grade levels. Some MSPs involve several IHEs and a single school district; institutional partnerships may involve a single IHE and district. Other partnerships may involve multiple IHEs, school districts, disciplines, geographical areas, and institutions, such as museums. Most MSPs are funded and managed through higher education partners. (National Science Foundation, 2005).

NSF has a long record of experience in STEM teacher preparation and professional development through programs such as the Urban Systemic Initiative (USI), Rural Systemic Initiative (RSI), Graduate K-12 (GK-12), and the Lewis Stokes Alliance for Minority Preparation (LS-AMP). The agency is one of the major funders of university-based research and its reputation in the academic community provides it with a high level of credibility and prestige.

In addition to the NSF-MSPs, the Department of Education funds a program called the Mathematics Science Partnership, which provide considerably more modest funding to states on a formula basis. The ED-MSPs and NSF-MSPs do a limited amount of collaborating, sharing information through www.mspnet.org, the web portal for the NSF projects, and in some states where both agencies fund partnerships, such as Colorado. Since the establishment of the two programs, support has varied in the Congress and the executive branch for the programs, with the Education MSPs receiving more funding in some years, causing a loss in NSF support.

In addition to the MSP partnerships, NSF funds two types of research and analysis projects that study and support the initiative. These projects are called Research Evaluation and Technical Assistance (RETA) projects and Knowledge Management Dissemination (KMD) projects. RETAs include an evaluation-focused program that organizes conferences

and publishes findings on partnership activities, quantitative data collection of all MSP partners, studies of course and program reforms, and a Web portal for all MSP activities.

Each partnership conducts regular internal evaluation, submits an annual report, and participates in the MSP Management Information System (MSP-MIS) data collection effort. Information about MSP initiatives and activities are collected in an online RETA, www.mspnet.org, that provides a showcase for each project as well as resources on partnership activities, a library, and discussion groups.

MSPs are funded for five years, RETAs for varying periods of time, and KMDs for three years. Funding for the first MSP cohort is scheduled to end at the close of FY 2007. In 2006, NSF announced a competition for a limited number of new MSP and RETA projects.

Most of the partnerships are funded through and managed by IHEs and guided by partnership committees from IHE and K-12 partners. Several partnerships include leadership with involvement in prior NSF programs, such as Urban Systemic Initiatives or Rural Systemic Initiatives, and several have experience in other K-16 partnership activities at the state level (such as the Partnership for the Reform and Improvement of Science and Mathematics, or PRISM, in Georgia, and Vertically Integrated K-16 MSP and Change and Sustainability in Higher Education KMD in Maryland).

Funding for the partnerships varies according to type. Comprehensive partnership models may involve both mathematics and science, partners in both elementary and secondary levels, and may work across several states. Comprehensive projects have been funded in the \$20-million range. Targeted partnerships may work with one segment of K-12 and/or a specific STEM discipline, and are funded for under \$10-million. There is greater variation in funding for the RETA and KMD projects, which are granted to a wider variety of organizations than the partnerships, including research and evaluation firms as well as university system offices.

Faculty participation in the first years of the partnership, according to the annual MSP data collection, involved a majority of tenured faculty (53.1%). Faculty identified themselves overwhelmingly as belonging to STEM disciplines (62.2%). Nearly a quarter identified themselves as education faculty (Silverstein, Bell, Frechtling & Miyaoka, 2005). Nearly 70% had been involved in other K-12 reform efforts. Faculty spent a substantial amount of time on partnership efforts, with nearly 60% contributing 81 or more hours per year to the partnerships (Silverstein et al., 2005).

Driving/Restraining Forces in STEM Engagement

Participation in the NSF Math Science Partnerships provides several opportunities and challenges for STEM faculty. Driving, or motivating, factors include the opportunity to participate in the NSF initiative; possible professional development opportunities; release time; additional support; and the opportunity to work with colleagues from across IHE and K-12 sectors. Numerous factors may restrain STEM faculty engagement in partnerships. These include the delivery of rewards and incentives, the ambiguous role of faculty outreach, insufficient support for scholarship in teaching activities, and perceived prestige related to partnership activities. Fairweather (2005) has demonstrated that negative reinforcement, including pay, follows outreach activities by faculty in comprehensive institutions. Additionally, the great distinction between the preparation, autonomy, and practice of

college faculty and K-12 teachers creates an organizational and cultural divide between two segments of an apparently similar profession (Earley, 2005; Earley & Ross, 2006).

The NSF-MSPs provide an opportunity to overcome those organizational divides and disincentives. Early evidence from both partnerships and RETAs show mixed results resulting from both driving and restraining factors. The driving forces for partnership (funding from a prestigious agency with a track record in supporting work across disciplines and sectors), combined with the reality of establishing and managing complex projects, show a complex picture of noble efforts and challenging reality. The concept of partnership has multiple meanings and enactment of the partnerships has taken place in a framework of good will, little empirical background, and multiple interpretations.

Early Evidence

Funding for the first cohort of MSPs will conclude officially at the end of FY2007. Research data from several partnerships, RETAs, and KMDs are providing intriguing findings. Data sources include the MSP-Management Information Survey, the annual reports submitted by each MSP-funded initiative, and research projects conducted by several MSPs as part of their evaluations. One RETA, the *Effect of STEM Faculty Engagement in MSP: A Longitudinal Perspective* (Westat, 2006), has measured faculty engagement in several partnerships. The Change and Sustainability in Higher Education (CASHÉ) KMD, has studied curricular and program changes among a large sample of partnerships in 2006, and is developing case studies of a number of MSPs to gauge the partnerships' abilities to sustain their activities beyond the funding period.

Another RETA, Building Evaluation Capacity (<http://be.mspnet.org>), has conducted annual conferences engaging both MSPs and evaluation projects to share data and findings from project activities and related research. Several of the MSPs have done research on aspects of faculty engagement within their own projects, including North Cascades, SCALE, and PRISM.

Data from Studies on Partnerships

STEM faculty engagement case studies. The Effect of STEM Faculty Engagement in MSP: A Longitudinal Perspective is a four-year RETA conducted by Westat that has developed case studies of eight partnerships in Cohort I (ending in September 2007) and Cohort II (ending in September 2008). Westat also conducts the overall quantitative data collection, the MSP-Management Information System. The study posed six research questions, including methods that projects use to increase STEM faculty engagement, levels of involvement, policy implications, evolution of faculty engagement, and STEM faculty contribution to student achievement (Zhang & McInerney, 2006). Faculty from the partnerships that Westat studied closely reflect the profile of the MSP-MIS, with faculty shown as overwhelmingly white, male, tenured, and engaged previously in other types of partnership activities. The study has found that faculty involved in the partnerships are bound by traditional reward structures, and that many institutions do not reward and recognize outreach as an activity on par with traditional scholarly research. In addition, there are few prior studies that demonstrate rigorous experimental design and little comparable data available to gauge the impact of STEM faculty engagement in the MSPs or other

partnerships. Most STEM faculty activity in these cases involved teacher professional development; a role that takes different forms in different partnerships.

Zhang and McInerney note that “none of the partnerships are identical in their approaches and strategies.” (p. 9). They also cite concerns from faculty that include “examples of poor planning and management on the part of MSP projects,” including lack of clarity about faculty commitment, release time, and remuneration. Their findings note some institution-level changes, which is borne out by annual reports submitted to NSF.

Early findings from the CASHE Project. The Change and Sustainability in Higher Education (CASHE) project is a Knowledge Management Dissemination project established in FY 2005. CASHE’s charge is to survey the landscape of partnerships and to synthesize and analyze activities of IHEs involved in the partnerships. In 2006, CASHE issued reports on curricular and program design in 21 of the partnerships. Its study revealed that all of the projects studied engaged in some form of curricular change, particularly in the area of preservice teacher preparation and professional development for K-12 teachers. In nine of these MSPs, course or program redesign involved more than one IHE. Nearly a third of the MSPs engaged in cross-institutional team planning to develop new courses or curricula, and over 85% provided summer institutes to provide professional development. Activities connected to these redesigns included content seminars, multidisciplinary science courses, redesigned teacher preparation curricula, and development of new academic programs that align with state and disciplinary standards (CASHE Project, 2006; Maloney, Earley, Mangurian, & Millman, 2007; Benson, Hamos, Langenberg, Maloney, & Shapiro, 2006). The CASHE study found that “curricular changes varied so widely across the MSP projects that they are difficult to classify,” and that initial review failed to identify the leadership role of STEM or education faculty in the changes studied. CASHE has embarked on a study to measure the extent of MSP activities on institutional change, and change in faculty practice.

Reports from the Partnerships

Several MSPs have issued reports based on studies of their activities. This analysis includes a brief description of four of these MSP-related reports. These reports include findings from two of the largest (comprehensive) MSPs, the Partnership for Reform in Science and Mathematics (PRISM) and System-Wide Change for All Learners and Educators (SCALE). The other reports are from a targeted MSP, the North Cascades and Olympic Science Partnership, and an institutional partnership with the University of Pennsylvania Science Teachers Institute.

North Cascades and Olympic Science Partnership (NCOSP). NCOSP is based in Washington State and is headquartered at Western Washington University (WWU). IHE partners include WWU, Everett Community College, Northwest Indian College, Skagit Valley College, and Whatcom Community College. NCOSP K-12 partners include 26 school districts. This MSP focuses on improving teaching and learning in both K-12 and higher education by working on science curricula in grades 3 through 10. Authors of one NCOSP study have echoed the view that there is little empirical data defining or describing partnerships like the MSPs (Landel & Ohama, 2006). Authors utilized a case study approach, involving review of report documents, focus groups, and interviews with partnership participants. Findings uncovered by the study included a strong focus on partnership activity and steps taken to clearly define the partnership’s values and beliefs.

Strong aspects of the partnership are a focus on shared vision, distributed leadership, a safe learning environment, and respectful relationships between partners. Another successful aspect of the partnership is careful identification and selection of IHE faculty partners.

Partnership for Reform in Science and Mathematics (PRISM). PRISM is one of the largest and most complex of the MSPs. PRISM is sponsored by the University System of Georgia in partnership with the Georgia Department of Education. This project has been developed in a state with a longstanding K-16 tradition and unusually close coupling in the development of policy and practice between higher education and K-12. PRISM's chief IHE partners are the University of Georgia, Georgia State University, Armstrong Atlantic State University, Coastal Georgia Community College, Georgia Perimeter College, and Georgia Southern University. PRISM's MSP work includes 10 strategies to support partnership activity and engage educational change. The *Strategy 10* plan calls for the MSP to "[p]rovide a reward structure in universities to encourage faculty to sustain involvement in improving science and mathematics teaching and learning in K-12 schools" (Kutal, Butler, Connor, Ellet, Henry, Hessinger, Kettlewell, Kozaitis, Miller, Rich, Vandergrift, & Zinsmeister, 2006). PRISM leadership and faculty worked to develop recommendations on changes in rewards and recognition for faculty engagement in K-12 reform, and resulted in adoption of policy by the Georgia State Board of Regents to support faculty involvement in partnerships that are articulated at the department, division, and institutional level, and is customizable for institutional type. This policy provides evidence of the sustainability of PRISM's partnership work in public institutions within a state system, a lasting result of the complex work of the partnership.

System-Wide Change for All Learners and Educators (SCALE). SCALE is a comprehensive MSP housed at the University of Wisconsin Center for Educational Research. Its IHE partners include WCER, California State Dominguez Hills and California State Northridge. SCALE works with four urban school districts around the country. SCALE engages both STEM and education faculty directly in its activities, which focus on improving P-12 science and mathematics education.

University of Pennsylvania Science Teachers Institute (Penn STI). Penn STI is an institutional partnership housed at the University of Pennsylvania, with involvement from the Graduate School of Education and several STEM departments within the School of Arts and Sciences; the partnership is managed through Penn's chemistry department. The Penn STI's purpose is to train and retain science teachers in both elementary and secondary grades. The MSP provides "intensive" master's degree programs and works with 20 area schools or districts in the mid-Atlantic region. Penn's professional development model was lauded in *Rising Above the Gathering Storm* (2005). Penn's study focuses on the role of STEM faculty instructional beliefs. The authors of the case study found that faculty beliefs inform and have an impact on reform activities and that reform does not occur without a change in belief (Jacobs, Yoon, & Otieno, 2007).

Discussion

Partnership activities between K-12 systems and higher education have been an attractive policy tool for a number of years. Many of these partnerships have involved school reform activities. The National Science Foundation Math Science Partnerships provide

significant funding to several dozen partnerships that have concentrated on reforming STEM curricula at both the K-12 and IHE levels. NSF expected the partnerships to develop their work in alignment with five key features and to provide regular evidence of accomplishments.

MSPs were conceived as a policy solution intended to function in a complex setting of institutions and systems with differing cultural expectations, reward structures, and management practices. The MSPs were embarking on large-scale partnership work in which there is little prior empirical data, incorporating research and evaluation activities that vary from project to project. The NSF-MSPs were placed in political competition with the very different partnerships funded by the Department of Education, causing NSF to lose funding in several budgets.

As the first cohort of projects conclude the major portions of their work and affiliated MSP programs present studies of their efforts, a number of common findings have emerged. Establishing and maintaining partnership is difficult and challenging work and the lack of substantial prior research and development in this arena places great responsibility upon the stakeholders to find their way in building and maintaining partnership. Although the partnership projects have very different emphases, the profiles of higher education faculty involved are quite similar. Active STEM faculty participants in the first cohorts are overwhelmingly white, male, tenured, and experienced with different types of partnership work. Newer or non-tenured faculty, including education faculty, participated in the partnership projects in much smaller numbers.

Faculty participating in the partnerships were expected to engage in activities beyond the scope of their regular duties and faculty in several MSPs reported that unclear expectations, ambiguous support, and lack of rewards hindered their activities. On the other hand, faculty in a number of MSPs reported increased engagement in curricular reform and involvement in partnership, including a new understanding of the roles of K-12 faculty. One MSP, representing a partnership including a state board of education and the state system of higher education, was responsible for developing a policy on faculty rewards adopted by the higher education Board of Regents, a case where policy development was driven by participants and not policymakers.

Other challenges inherent in the MSP initiative include a short timeframe—five years to establish, maintain, and attempt to sustain a partnership in some manner. The focus on STEM faculty engagement in these partnerships has been key to involving disciplinary faculty in school reform, but the expertise of education faculty may be marginalized in these partnerships.

Finding ways to measure the effectiveness of these projects is a matter of some contention. A recent report issued by the American Competitiveness Council called for such projects to engage in rigorous research design, highlighting randomized control trials, a method not used or suggested for the NSF projects. Mixed-methods longitudinal studies may provide the best means by which to determine the success of the MSPs after they have reached their formal conclusion.

Whether actions such as the faculty reward policy are adopted in other states or systems as a result of the MSP initiative remains to be seen. Researchers involved in the STEM faculty case studies write that “[a]lthough collaboration is quite easy to extol, it is difficult to achieve” (Zhang and McInerney, 2006, p. 2).

The NSF Math Science Partnerships will continue for several more years, as the second, third, and final cohorts continue their project work. Sustainability of these partnerships may take different forms, such as the adaptation of the UTeach model being imported from the University at Texas Austin to several other institutions through funding from the ExxonMobil Foundation.

These partnership activities provide an opportunity for scholars and practitioners in higher education and educational administration to analyze and recommend ways in which partnership activities can be understood, developed, and managed. Faculty engagement and rewards warrant further study, innovation, and activity.

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