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Appendix A

MSP Course and Curriculum Report

Report on Course and Curriculum Changes in Math and Science Partnership (MSP) Programs

Change and Sustainability in Higher Education (CASHÉ)

June 2006

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Report on Course and Curriculum Changes in Math and Science Partnership (MSP) Programs

Change and Sustainability in Higher Education (CASHÉ)

June 2006

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Introduction and Overview

The National Science Foundation's Math and Science Partnership (MSP) grants support innovative programs that are designed to improve K-16 student achievement in mathematics and the sciences. One of the goals of the MSP program is to foster systematic change within institutions of higher education (IHEs) in order to improve the teaching and learning of mathematics and science at all levels of education. MSP projects work to improve the quality of current and future STEM (science, technology, engineering, and mathematics) faculty and teachers through institutional changes that include course and curricular innovations, the development of new pathways for K-12 STEM teacher preparation, and professional development for STEM faculty and teachers. The Change and Sustainability in Higher Education (CASHÉ) project, housed at the University System of Maryland, is conducting a three-year study that seeks to document curriculum transformation, faculty engagement, and sustainable change among IHEs that are involved in MSP projects. The major focus of this study is on ways in which MSPs have engaged STEM higher education faculty in focusing on the quality of STEM undergraduate education, strengthening their teaching practices, and expanding the scope of their work to encompass a K-16 perspective, including the improvement of K-12 STEM education and the preparation of future teachers.

While there is a substantial body of literature that focuses on change in higher education (see Kezar, 2001, and Kezar & Eckel, 2002, for a synthesis of theory and research) and the nature of school-university partnerships (Greenberg, 1991; Timpane & White, 1998; Verbeke & Richards, 2001; Wallace, 2003; Wiseman & Knight, 2003), few studies focus specifically on curricular change in the context of these relationships. Under the auspices of the CASHÉ project, this current report attempts to bridge this gap by concentrating on changes in higher education courses and programs (both STEM and teacher preparation) that are made in the context of a collaborative MSP relationship.

During this first phase of the study, the CASHÉ project team conducted an analysis of MSP-supported curricular initiatives within a subset of MSP projects from across the nation that reported significant changes among partner IHEs. The findings suggest that course and curricular changes have occurred across the MSP programs, that the majority of these changes are in certification and professional development programs for pre-service and in-service K-12 STEM teachers, and that there is an emphasis on the development of new pathways for the preparation

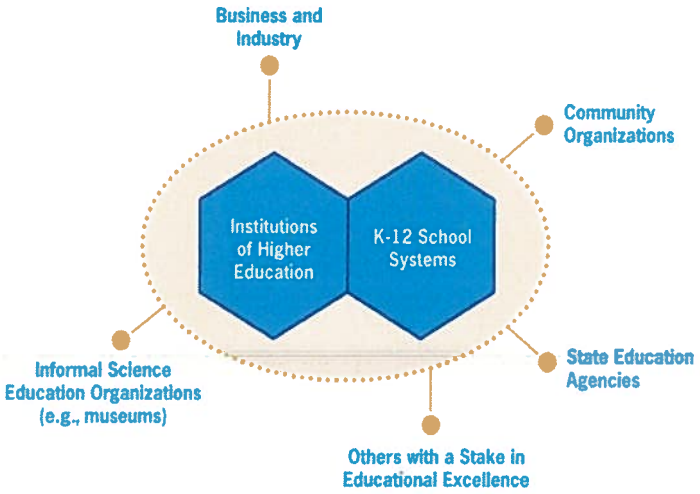
of future K-12 teachers in the STEM disciplines. The data also suggest that these changes are occurring at the local level rather than the institutional level, involving individual faculty members who are engaged in specific MSP-supported activities (as opposed to department-wide initiatives or collaborative teams). This report offers a summary of the study's methodology, data, findings, and implications in these areas.

The second phase of this study, which will begin in Fall 2006, will use case study methodology to examine the extent to which STEM faculty are actively engaged in these curricular innovations, the relationship between STEM faculty and teacher education faculty in these efforts, the institutional reward structures that support or hinder their participation, and the broader impact of MSP-related initiatives on STEM undergraduate courses and programs among participating IHEs.

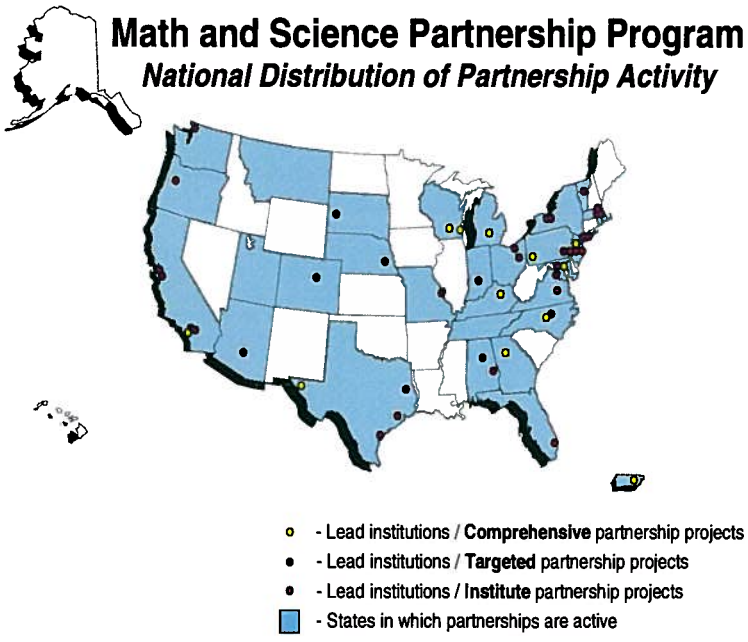
Background and Context

The MSP program is an important initiative from NSF and the broader scientific community that addresses the urgent need to improve STEM education in the 21st century and expand the pipeline of students majoring in STEM disciplines. The MSP initiatives recognize that in order to prepare the next generation of STEM professionals, we must have scientifically, technologically, and quantitatively literate K-12 teachers who are able to prepare the next generation of college students. These needs are likewise substantiated in several recent national reports (e.g., *A Commitment to America's Future: Responding to the Crisis in Mathematics and Science Education; Before It's Too Late: A Report to the Nation from the National Commission on Mathematics and Science Teaching for the 21st Century; Learning for the Future: Changing the Culture of Math and Science Education to Ensure a Competitive Workforce; Tapping America's Potential: The Education for Innovation Initiative; To Touch the Future: Transforming the Ways Teachers Are Taught*). At the same time, shortages of qualified K-12 STEM teachers are well-documented, a crisis that is expected to continue in the foreseeable future (Curran, Abrahams, & Manual, 2000; Gerald & Hussar, 2003; U.S. Department of Education, 2000, 2002). Thus, MSP projects operate in a collaborative research and development environment that seeks to increase the number of new, highly proficient STEM teachers through innovative teacher preparation programs, to improve the quality of the current STEM teacher workforce through professional development, and to enhance the quality of

STEM education within IHEs for all students. Central to the success of the MSP programs are strong partnerships among K-12 school systems and IHEs that facilitate linkages to other key stakeholders on the local, state, and national levels. (See Figure 1.) Such initiatives are grounded in the recognition that the "nature of school and university partnerships has changed so that collaboration now represents a real opportunity to make systemic change and improvement" (Verbeke & Richards, 2001). Several NSF Research, Evaluation, and Technical Assistance (RETA) projects are currently studying the dynamic nature of such collaborations among MSP partnerships (e.g., Kingsley, O'Neil, & Usselman's Alternative Approaches to Evaluating STEM Education Partnerships).



In 2002, NSF funded its first cohort of MSP projects. There are currently 48 MSPs across the nation. (See Figure 2.) Twelve are designated as comprehensive projects that engage IHEs and the entire K-12 spectrum. Twenty-eight are designated as targeted projects that engage IHEs and specific grade levels (i.e., elementary, middle, or high school). The remaining eight are institute partnerships that focus on content and leadership. By design, the five key features of all MSP projects include: (1) challenging STEM courses and curricula; (2) enhancement of teacher quality, quantity and diversity; (3) partnerships among STEM faculty at all levels; (4) evidence-based course and curricula design; and (5) institutional change and sustainability.



Methodology

In November 2005, NSF charged the CASHÉ project team to study a subset of the MSPs to analyze the nature of curricular changes within IHEs that were reported as outcomes from their involvement in the project. Twenty-four MSPs were identified by NSF program officers as offering particularly promising examples of institutional change. The CASHÉ project team collected data on 21 of these projects in the form of annual reports, internal and external evaluation summaries, and other project materials. These data were categorized and archived and serve as the basis for the current study.

A profile of the 21 participating projects is shown in Table 1. These partnerships represent a cross-section of 11 targeted, 8 comprehensive, and 2 institute MSPs from NSF cohort years 2002, 2003, and 2004. Fourteen of the MSPs (Boston Science Partnership, Cleveland MSP, Consortium for Achievement in Mathematics, Focus on Mathematics, Greater Birmingham, Greater Milwaukee, Greater Philadelphia, Preparing Virginia's Mathematics Specialists, Project Pathways, Puerto Rico MSP, Revitalizing Algebra, Rocky Mountain, SCALE, and VIP K-16) are primarily urban projects. Four projects (Appalachian, FOCUS Irvine, MSP-Southwest PA, and North Cascades) focus on rural communities, while the remaining three (El Paso, Penn Science Teacher Institute, and PRISM) serve both urban and rural constituencies. Eighteen of the partnerships involve multiple local school districts. Among the 21 MSPs, 72 colleges and universities and 8 other participating organizations (e.g., research institutes or educational associations) are represented. Eleven of these projects involve three or more IHEs. Six of the partnerships (Appalachian, El Paso, Greater Philadelphia, North Cascades, Project Pathways, and VIP K-16) include community colleges.

To guide this study, the CASHÉ project team developed a set of six overarching questions for analyzing the MSP project data related to curricular change among participating IHEs. Similar to the change model developed by Clark, Froyd, Merton, and Richardson (2004) for engineering education, these questions recognize that curricular change is not merely the development of a new "product" or "deliverable," but a "dynamic entity" whose growth and continuous evolution must be sustained over time. As a result, the analytic framework for this study focuses not only on the content of these curricular changes, but also on the mode, process, participants, audience, and external context. Thus, the guiding questions for this study are as follows:

(1) What type of curricular change is involved (i.e., does the change involve the development of new courses, programs, certifications, or degrees, and/or does it involve the redesign of existing courses, programs, certifications, or degrees)?
(2) Who is/are the primary audience(s) for the change (e.g., pre-service STEM teachers, in-service STEM teachers, IHE undergraduate students, IHE graduate students, IHE faculty, or others)?
(3) Who is responsible for these changes, and are they the result of the efforts of individuals or teams?
(4) Are these changes linked to external educational standards (i.e., local, regional, state, or national)?
(5) Do these changes involve non-curricular or non-credit activities (e.g., workshops or professional development programs)?
(6) What types of evidence support these change claims among IHEs?

Results and Discussion

The information obtained from the analysis of the raw data using the six guiding questions above is presented in Tables 2, 3, and 4. The aggregated data in Table 2 show several important outcomes. All 21 of the selected MSP projects were engaged in the creation or redesign of higher education courses, and in every case these changes were part of new or redesigned programs, curricula, and/or teacher certification pathways. These findings suggest that course development and redesign are not occurring in isolation, but rather as part of broader institutional change efforts. In nine of the MSP projects, these creation and redesign efforts involved more than one IHE partner. At the same time, however, the type and nature of the course change varied across the projects. Eighteen of the projects developed new or redesigned professional development courses for in-service teachers, 16 developed new or redesigned courses for STEM undergraduates (since many of the courses in this second category overlap between STEM majors and STEM teacher candidates, it was difficult to make distinctions), and 10 developed new or redesigned courses specifically for pre-service teachers. Among the MSPs, all of the constituent groups (pre-service teachers, in-service teachers, and STEM undergraduates) appear to be well-served.

Seven of the projects (Appalachian, Cleveland MSP, Greater Milwaukee, North Cascades, Puerto Rico MSP, Revitalizing Algebra, and SCALE) developed new or redesigned courses for all three constituent groups (pre-service teachers, in-service teachers, and STEM undergraduates). Among the remaining projects, nine (Consortium for Achievement in Mathematics, El Paso, FOCUS Irvine, Greater Philadelphia, MSP-Southwest PA, Penn Science Teacher Institute, Preparing Virginia's Mathematics Specialists, PRISM, and Project Pathways) developed new or redesigned courses for two constituent groups, while five (Boston Science Partnership, Focus on Mathematics, Greater Birmingham, Rocky Mountain, and VIP K-16) focused their efforts on a single constituent group. Approximately one-third of the selected MSPs were engaged in STEM course development or redesign at the graduate level.

In terms of the subject matter and academic focus of these newly created or redesigned courses, there was substantial diversity both within and across MSP projects, including content deepening seminars (MSP-Southwest PA), multidisciplinary integrated science courses (Penn Science Teacher Institute), courses that focus on effective teaching strategies and practices (Project Pathways), courses that prepare in-service teachers for "highly qualified" status under *No Child Left Behind* (Cleveland MSP), standard teacher education course sequences across multiple higher education institutions (Appalachian), and courses that provide a forum for the exploration of such factors as gender, race, ethnicity, and class that impact STEM teaching and learning (Revitalizing Algebra).

In nine of the MSP projects, STEM course development or redesign efforts were the product of or resulted in new academic programs. Because new programs generally go through a rigorous review process in higher education institutions, there is high likelihood that these resulting curricular changes will be sustainable. Program reviews generally involve multiple faculty members and formal evaluation and approval by a committee or review panel at the departmental or school/division level (see Barak, 1982, for a detailed discussion of the program review process in higher education). For many colleges and universities, particularly those in the public sector, this review process often involves an external regulatory agency as well (e.g., university system office or state higher education board). Thus, the development and implementation of a new academic program requires substantial buy-in at a variety of levels at an institution, particularly with respect to the allocation of resources to support the program. In light of such investments, the course and curricular changes that are supported by and result from

MSP participation (particularly when linked to new academic programs) are likely to be sustained by IHEs over time.

In seven of the projects, newly developed or redesigned courses were in close alignment with district, state, or national education standards. In at least 13 cases, the newly developed or redesigned courses, curricula, or programs directly involved either K-12 or IHE administrators. In 11 of the projects, the newly developed or redesigned programs included extracurricular, non-credit, or informal activities. For example, through Maryland's VIP K-16 EXPERT Program, high school science teachers spent a summer working in a research laboratory and then continued working together as a learning community during the subsequent academic year. Another major pathway for the delivery of newly developed or redesigned programs was through summer programs or institutes; 18 of the MSP partnerships used this model. While some focused on the recruitment and preparation of future teachers (e.g., PRISM's Summer Bridge Institute, Project Pathways' Summer Certification in Secondary Mathematics Program) or the professional development of in-service teachers (e.g., Greater Birmingham's Summer Content Institutes, Greater Philadelphia's Secondary Education Summer Enrichment Program), others were designed specifically for K-12 students (e.g., Puerto Rico's summer camps for 6^{th} to 12^{th} grade students, Rocky Mountain's Center for Math, Science, and Environmental Education summer camp).

Six of the MSPs explicitly reported the use of a team or consortium approach for the development of new or redesigned courses. Notable examples include the Boston Science Partnership, which involved vertical teams of IHE faculty and K-12 teachers working together to create summer professional development courses for K-12 teachers, and the Appalachian MSP project, which used a team-based approach to develop a variety of courses for pre-service teachers. Appalachian formalized its consortium-building efforts through the creation of the Partnership Enhancement Program (PEP), which partners local school districts with IHEs to work on projects in targeted areas of need, including curricular issues. This program was designed to establish a network of smaller partnerships across all levels of the MSP and was based on the recognition that "micro-investments" were an effective means of initiating new working relationships to address shared challenges, needs, goals, and interests. In an external evaluation of Appalachian's PEPs, K-12 teachers have reported a sense of empowerment resulting from their participation, particularly in having the opportunity to apply their classroom

experiences in addressing larger-scale problems and issues. Participating IHE faculty, in turn, have shared that they now have a better appreciation for and understanding of curriculum and instruction at the K-12 level.

In the vast majority of the 21 MSP projects that were studied, course development or redesign activities predominantly appeared to be the product of individual faculty members. However, from the data provided, it is difficult to know if this is indeed the case. Given the nature of formal and informal collaborations and exchanges among faculty at IHEs, course development and redesign efforts are likely to reflect the input and expertise of multiple faculty members. The nature of collaborative efforts among MSP faculty participants both within and across partner IHEs warrants additional investigation and is a rich area for further inquiry. For example, what structures and incentives have MSPs created in order to encourage and reward formal and informal collaborations of this nature? What factors and conditions either facilitate or hinder such efforts? To what extent do such models as faculty learning communities (e.g., those introduced by VIP K-16) provide opportunities for collaborative course development or redesign activities?

As presented in Table 3, these 21 projects have developed or redesigned a total of 169 STEM-related higher education courses through the scope of their MSP work. For the purposes of this study, a redesigned course was operationally defined as a course identified by the MSP project staff as having gone through substantial revision, modification, or restructuring as part of their MSP participation. Interestingly enough, there is no apparent correlation between the type or size of the MSP (as determined by the number of institutional partners) and the number of newly developed or redesigned courses. Sixteen of these projects have developed or redesigned less than 10 courses, while the remaining five (Boston Science Partnership, Cleveland MSP, El Paso, Greater Philadelphia, and PRISM) have developed or redesigned 10 or more. These courses span multiple disciplines within mathematics and the sciences and range from classroom-based content and pedagogy courses to labs, internships, and seminars. Several projects specifically pointed to the incorporation of new inquiry-based techniques or the deepening of content matter as a significant component of new course development or revisions to existing courses, while others mentioned the integration of new theories and research on teaching and learning. For some projects, the impetus for change was to align K-12 and higher education courses and curricula with outside standards. For example, Rocky Mountain reported

that its newly developed IHE courses focused on district needs and the state's performance-based licensing standards for teachers in science and mathematics.

Fifty-four (32%) of the newly developed or redesigned courses targeted pre-service teachers; two-thirds of these courses were math or math education courses. The remaining were spread nearly equally among the various science disciplines (e.g., biology, chemistry, earth/space science, physics, and engineering). Among the 21 projects, there were no reports of the development or redesign of science education courses for pre-service teachers. Ninety (53%) of the newly developed or redesigned courses targeted in-service teachers. In contrast to courses for pre-service teachers, almost half (40) of these courses were in the science disciplines, while 29 were in math education or science education and 21 were in math. This difference likely reflects the rapidly evolving nature of curricular content in the sciences and the need for in-service teachers to continuously learn new subject matter. Only 25 (15%) of the newly developed or redesigned courses were for STEM majors or graduate students. Thus, the vast majority of the changes as measured by newly developed or redesigned courses within participating IHEs focused on pre-service or in-service teachers. Typically, these two groups represent only a small fraction of students enrolled at most IHEs; this is particularly true among research universities and many comprehensive universities. The resulting implication is that MSPs are more likely to have a greater impact on the STEM curriculum within teacher education rather than a broad-based impact on the STEM curriculum for the general undergraduate population among participating IHEs.

A detailed profile of the types of IHE changes reported by each of the MSPs is provided in Table 4. Based on the materials provided to us by the 21 projects, we assigned the primary impact of the reported changes to one of two constituencies: (1) those directly involved in K-12 education (i.e., pre-service or in-service teachers), or (2) undergraduates enrolled in STEM courses (i.e., both majors and non-majors). In some cases, these student populations are intermixed, as many STEM courses that serve pre-service teachers also serve STEM majors, in which case the changes impact both groups. In fact, it was often difficult to discern differences between STEM courses for pre-service teachers and those for other undergraduate students, as there was substantial overlap. Nevertheless, it is clear that the IHE changes summarized in Table 4 primarily affect individuals who are already committed to becoming teachers or who are pursuing teacher certification. In addition, some MSP projects have developed courses and

programs with a specific focus on recruiting more STEM majors into teaching, including FOCUS Irvine's summer program for community college students and Project Pathways' summer certification program for mathematics majors. However, the broader question of curricular change both in K-12 and higher education in order to recruit and retain more STEM students to begin with is an important area that warrants further exploration.

Conclusions

Based on this analysis of 21 selected MSP projects, there is strong evidence that participating IHEs have engaged in significant curricular development initiatives in support of STEM teacher preparation programs. The data presented in this report support the following general observations:

- Every MSP, and most of the IHEs involved in these projects, have developed or redesigned courses through their MSP funding.
- Every partnership has developed new programs, degrees, or teacher certification pathways through their MSP funding.
- Most of the MSPs have focused their efforts on the K-12 side of the partnerships, including pre-service and in-service courses, with fewer resources explicitly devoted to changing STEM courses for general education requirements, undergraduate majors, or graduate programs.
- Course design efforts have taken multiple forms but predominantly reflect the work of individuals or small teams within an MSP project.
- In addition to new courses, newly developed extracurricular, non-credit, or informal activities were reported by a number of the projects.
- Although the majority of new or redesigned professional development courses and activities involved faculty and teachers, many MSP project administrators were also directly involved in this work.
- The degree and nature of curricular change activities did not appear to be dependent on the initial year of the MSP grant, size of partnership, or type of partnership.

Limitations of the Analysis

One of the major limitations of this study was that it relied on the secondary analysis of written, self-reported materials that were submitted by individual MSP projects (e.g., annual reports, internal and external evaluation reports, etc.). In some instances, this information was supplemented by Web-based materials gathered by the CASHÉ project team. As a result, the quantity and quality of available data varied widely across the 21 projects. In the next phase of this study (see "Next Steps" below), it will be important for us to triangulate these findings with other project-related evidence, including data collected from interviews and site visits, data from the MSP Management Information System (MIS), data from annual surveys of projects and partners (e.g., WESTAT), and data from MSP-related workshops (e.g., National Research Council).

Another challenge related to this study was that the curricular changes varied so widely across the MSP projects that they were often difficult to classify. In some cases, it was difficult to determine from the materials provided whether the change was a new course, the alteration of an existing course, or the development of a nontraditional course such as a professional development workshop during a summer institute. In addition, while several projects did mention the alignment of new courses and programs with external standards, particularly the alignment of pre-service and in-service IHE courses with local school district standards, the extent to which these alignment processes were mutual was unclear (i.e., whether K-12 and IHE partners equally influenced each other's change processes and/or if such changes flowed in both directions in the partnership). From the materials provided, it was also difficult to uncover the original impetus or motivation for many of the curricular changes and the extent to which STEM faculty versus teacher education faculty (or both groups working together) were primarily responsible for these change initiatives. This is an important topic that warrants further investigation during the upcoming site visits with select MSP projects. Also, the specific manner in which MSP funds were spent in order to support these curricular changes was not apparent from the data we collected from participating projects (i.e., purchasing new instructional materials and equipment, funding faculty course releases, hiring external consultants, offering more sections to reduce class size). In order to examine these issues in depth, the CASHÉ project team plans to complete a comprehensive analysis of MSP project budgets and spending

patterns to see how participating IHEs have leveraged NSF funding for project activities related to curriculum development, faculty engagement, and sustainable change.

In addition to these limitations, there were other noticeable gaps in the study's findings. From our review of the project materials, we found only two mentions (Greater Philadelphia and PRISM) of plans for involvement with professional development schools (PDS), despite the fact that PDS is a well-established form of partnership in numerous districts and states across the nation. In addition, only one partnership (Rocky Mountain) made any direct mention of collaboration with other federally-funded K-12/higher education reform efforts, such as the Title II Teacher Quality Enhancement grants or U.S. Department of Education MSP grants. As we consider questions related to the sustainability of the changes that result from these MSP projects, it will be important to continue to examine the extent to which IHEs have successfully linked and integrated their MSP initiatives with other ongoing developments.

Next Steps

This report examined MSP curriculum development initiatives among participating IHEs as measured by changes to courses, programs, degrees, and teacher certification pathways. By beginning with relatively concrete, easily documented changes, the CASHÉ project team was able to discover a number of "wedge" issues that require further study using different approaches and methodologies. As highlighted in this report, these issues include the nature of faculty collaboration in the course development and revision process, motivating factors behind curricular change, the leveraging of institutional and grant resources for curricular change, and the broader long-term impact of MSP projects on STEM teaching and learning outside of pre-service and in-service teacher education.

It is important to acknowledge that curricular changes are not the only types of developments that have resulted from IHE participation in MSP projects. Changes in institutional culture, priorities, policies, recognition and reward structures, and incentives for faculty engagement in such initiatives are equally important to examine. The metrics for measuring changes in these areas are more complex, however, since they evolve over time and are not always readily documented. Also, it is often difficult to establish a cause-effect relationship when evaluating outcomes of this nature (i.e., differentiating which outcomes can be directly attributed to MSP participation and which outcomes would have likely occurred

anyway). Unlike curricular change, which can be demonstrated with such evidence as the creation of a new academic program, course, syllabus, portfolio of instructional activities, or set of learning outcomes, the evidence for institutional change is more subtle and requires deeper study for understanding.

In preparation for these challenges, the CASHÉ project team is drawing upon the expertise of its national Advisory Board to develop a conceptual framework and evidence-based protocol for conducting research in these areas, which will involve site visits to several MSP projects in Fall 2006 and Spring 2007. There are several overarching questions that will frame the next phase of this study: To what extent have institutional priorities and practices changed relative to MSP goals and objectives among participating IHEs? What conclusions can be drawn regarding the depth and breadth of IHE changes fostered through their involvement in MSPs, particularly in the areas of curriculum transformation and faculty engagement? Is there evidence of an emerging sea change within the STEM disciplines, or are we still looking at "a thousand points of light?" The answers to these questions and others will provide evidence regarding the extent to which MSPs have permeated the culture of higher education in ways that will leave permanent, sustainable, and embedded transformations leading to more robust teaching and learning across the entire educational spectrum.

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Table 1: Profiles of Selected MSPs

Partnership	Type	Initial Grant Year	States	Urban/ Rural	# Public School Systems	IHE Types			
	Targeted/ Comprehensive/ Institute					Comprehensive Institutions	Predominantly Undergraduate Institutions	Community Colleges	Other
Appalachian	C	2004	KY	R	53	5	3	2	1
Boston Science Partnership	T	2004	MA	U	49	3			
Cleveland MSP	T	2002	OH	U	1	2	1		1
Consortium for Achievement in Mathematics	T	2003	NJ	U	4	1			2
El Paso	C	2002	TX	Both	12	1		1	
FOCUS Irvine	C	2002	CA	R	3	1			
Focus on Mathematics (Boston University)	T	2003	MA	U	5	1			
Greater Birmingham	T	2004	AL	U	8	1	1		1
Greater Milwaukee	C	2003	WI	U	1	1	1		
Greater Philadelphia	T	2003	PA and NJ	U	46	5	6	2	
MSP-Southwest PA	C	2003	PA	R	40	1	3		
North Cascades	T	2003	WA	R	26	1	2	2	
Penn Science Teacher Institute	I	2004	PA	Both	20	1			

Table 1 (cont.): Profiles of Selected MSPs

Partnership	Type	Initial Grant Year	States	Urban/ Rural	# Public School Systems	IHE Types			
	Targeted/ Comprehensive/ Institute					Comprehensive Institutions	Predominantly Undergraduate Institutions	Community Colleges	Other
Preparing Virginia's Mathematics Specialists	I	2004	VA	U	5	3			
PRISM	C	2003	GA	Both	13	3	1		1
Project Pathways	T	2004	AZ	U	4	1		1	
Puerto Rico MSP	C	2003	PR	U	84	4			
Revitalizing Algebra	T	2003	CA	U	3	1			
Rocky Mountain	T	2004	CO	U	3	3	1		
SCALE	C	2003	WI	U	4		2		
VIP K-16	T	2002	MD	U	1	3		1	2

Table 2: Types of IHE Curricular Changes in Selected MSPs

Course or Program Change	**Appalachian**	**Boston Science Partnership**	**Cleveland MSP**	**Consortium for Achievement in Mathematics**	**El Paso**	**FOCUS Irvine**	**Focus on Mathematics (Boston University)**	**Greater Birmingham**	**Greater Milwaukee**	**Greater Philadelphia**	**MSP-Southwest PA**	**North Cascades**	**Penn Science Teacher Institute**	**Preparing Virginia's Mathematics Specialists**	**PRISM**	**Project Pathways**	**Puerto Rico MSP**	**Revitalizing Algebra**	**Rocky Mountain**	**SCALE**	**VIP K-16**
Project Type: Comprehensive [C], Targeted [T], or Institute [I]	C	T	T	T	C	C	T	T	C	T	C	T	I	I	C	T	C	T	T	C	T
Creation or redesign of courses	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Creation or redesign of pre-service STEM courses	X		X	X		X			X	X		X					X	X		X	
Creation or redesign for in-service STEM teachers (professional development)	X	X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Creation or redesign for STEM undergraduates	X		X	X	X	X			X		X	X	X	X	X	X	X	X		X	X
Creation or redesign involves STEM graduate program	X				X		X			X						X		X		X	
Creation or redesign involves summer professional development program	X	X	X	X	X	X	X	X		X	X	X		X		X	X	X	X	X	X

Table 2 (cont.): Types of IHE Curricular Changes in Selected MSPs

Course or Program Change	Appalachian	Boston Science Partnership	Cleveland MSP	Consortium for Achievement in Mathematics	El Paso	FOCUS Irvine	Focus on Mathematics (Boston University)	Greater Birmingham	Greater Milwaukee	Greater Philadelphia	MSP-Southwest PA	North Cascades	Penn Science Teacher Institute	Preparing Virginia's Mathematics Specialists	PRISM	Project Pathways	Puerto Rico MSP	Revitalizing Algebra	Rocky Mountain	SCALE	VIP K-16
Creation or redesign involves team or consortium approach	X	X									X	X								X	X
Creation or redesign involves more than one IHE	X				X				X		X	X		X	X	X				X	
Creation or redesign involves new programs, curricula, or certification pathways	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Creation or redesign generates new degree program(s)	X		X	X	X		X			X			X	X		X					
Creation or redesign involves external STEM standards	X	X	X			X									X			X	X		
Creation or redesign involves K-12 or IHE administrators		X		X	X		X	X	X	X	X	X	X			X	X			X	
Creation or redesign involves extra-curricular or informal activities			X			X	X		X	X	X				X		X	X		X	X

Table 3: Number of IHE Course Changes in Selected MSPs

Type of Course Created or Redesigned	**Appalachian**	**Boston Science Partnership**	**Cleveland MSP**	**Consortium for Achievement in Mathematics**	**El Paso**	**FOCUS Irvine**	**Focus on Mathematics (Boston University)**	**Greater Birmingham**	**Greater Milwaukee**	**Greater Philadelphia**	**MSP-Southwest PA**	**North Cascades**	**Penn Science Teacher Institute**	**Preparing Virginia's Mathematics Specialists**	**PRISM**	**Project Pathways**	**Puerto Rico MSP**	**Revitalizing Algebra**	**Rocky Mountain**	**SCALE**	**VIP K-16**	**Total Courses**
Project Type: Comprehensive [C], Targeted [T], or Institute [I]	C	T	T	T	C	C	T	T	C	T	C	T	I	I	C	T	C	T	T	C	T	
Pre-service math courses	2					2		6	4	5					8			1				**28**
Pre-service science courses	2			8											8							**18**
Pre-service math-ed courses				1		5														2		**8**
Pre-service science-ed courses																						
In-service professional development math courses	1		3		7					1	3			2			1		3			**21**
In-service professional development science courses			12		4					1		3	11			4	1		4			**40**
In-service professional development math-ed or science-ed courses		10	2		5		2		1	2	1		3	1		1		1				**29**
STEM undergraduate courses	2									7							2			4	6	**21**
STEM or education graduate courses	1															2		1				**4**
Total Courses	**8**	**10**	**17**	**9**	**16**	**7**	**2**	**6**	**5**	**16**	**4**	**3**	**14**	**3**	**16**	**7**	**4**	**3**	**7**	**6**	**6**	**169**

Table 4: Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Appalachian	Pre-Serv	x	Math (3), Science (3)	Redesign		2+2 teacher prep program, summer institute		x
	In-Serv	x	Math (2), Science (2)	New				
	IHE	x	2 graduate level online courses	New	Revised teacher prep program	1 course with community college, summer institute		
Boston Science Partnership	Pre-Serv						x	
	In-Serv	x	PD courses (3), Biology (1), Chemistry (2), ESS (2), Physics (1), Engineering (1)	New		K-12 summer program, "Vertical Teaming" (VT)		
	IHE	x				Faculty participate in VT		
Cleveland MSP	Pre-Serv	x				Faculty in Residence	x	
	In-Serv	x	Content-rich classes: Biology, Chemistry, ESS, Math, Physics	New		Math and science program, certification master's program (new), laboratory-based PD program, "Middle Grades Mentoring Initiative"		
	IHE	x				Faculty in residence, graduate certificate program in middle childhood science and math		

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Consortium for Achievement in Mathematics	Pre-Serv	x	PRAXIS review sessions in content areas	New	Developed consortium-wide curriculum frameworks	Summer institute, improvements to existing certification programs (focus on recruitment)	x	
	In-Serv	x			Revised special education math, general changes in math instructional materials	LC, lenses on learning, administrators' institute, math and science coaches, peer study groups		
	IHE	x				Summer institute, improvements to existing certification programs		
El Paso	Pre-Serv		History of Mathematics, Introduction to Research in Mathematics Education, Technology in the Mathematics Classroom, Number Theory and Algebra, Probability, Number Theory, Statistics in Research, Logic and Proof, Calculus and Analysis, Thermodynamics, Contemporary Topics in Biochemistry, Advances in Ecology Theory, Fundamentals of Earth Science				x	
	In-Serv	x		Both		Master of Arts in Teaching (MAT) with a major in science		
	IHE	x		Both				

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
FOCUS Irvine	Pre-Serv	x	Pre-MAT Calculus I and II			Teacher Education Academy (CC) scholars, classroom placements for undergraduates		x
	In-Serv	x	Secondary Math-ed (7)	New	Developed curriculum/pacing guidelines	Developed peer classroom observations protocols instructional programs		
	IHE	x				Undergraduate summer institute		
Focus on Mathematics (Boston University)	Pre-Serv						x	
	In-Serv	x	Mathematical Problem Solving, Fibonacci Minicourse	New		Master of Mathematics for Teaching (MMT) the Certificate of Advanced Graduate Study (CAGS)		
	IHE							
Greater Birmingham	Pre-Serv	x	Math and engineering summer courses	New		Funding and recruitment of under-represented math and science teachers	x	
	In-Serv	x	Math and engineering summer courses	New	Assessment of needed curricular change	Summer certification program for math and science, peer mentoring, training on pedagogy and instructional practices		
	IHE	x	Math (4)	Redesign	Changes to math curriculum	Workshops on mathematics, summer engineering projects for high school students		

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Greater Milwaukee	Pre-Serv	x	Math for future teachers	New		2+2 program, Cooperative Urban Teacher Education Program	x	
	In-Serv	x	Math courses for teachers in grades 1-8	New	Alignment, implementation of contemporary mathematics "core plus" curriculum	Math tutor program		
	IHE	x	Elementary Grades (1-6) Math	New				
Greater Philadelphia	Pre-Serv	x	Biology, Math (2), Education Chemistry Science	New		Science education, math and science certification, "Secondary Education Summer Enrichment Program"	x	
	In-Serv	x	Summer content institutes in Biology, Chemistry, ESS, and Math	New		Professional development program, teacher mentoring program		
	IHE	x	Biology, Chemistry, Math-ed, ESS-ed	New	Curriculum enhancement for core math and science courses at community college, STEM courses, internet based courseware for physics	America Counts math tutoring, intern certificate (teacher/student mentor), certification in environmental education, master's with certification program		

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
MSP-Southwest PA	Pre-Serv						x	
	In-Serv	x	Math (Algebra I/II, Geometry), Lenses on Learning Seminar, Content Deepening Seminars	Redesign	Development of Regional Science Curriculum Framework, curriculum alignment and pedagogical and course refinement	Academies and seminars, Teacher Leadership Action Academies, Teacher Fellow (TF) program, online chemistry tutoring program		
	IHE	x				Academies and seminars		
North Cascades	Pre-Serv	x			Changes and outcomes for pre-service content courses planned	Future teachers, scholarship program to attract more teachers, LASER Strategic Planning Institute for curriculum development, Curriculum Showcase, recruitment committee for increasing diverse pre-service teachers	x	
	In-Serv	x	SCED 201 Matter and Energy in Physical Systems, SCED 201 Matter and Energy in Earth Systems, SCED 201 Matter and Energy in Life Systems		Elementary schools already have adopted NSF-funded curriculum	Summer academies to develop teacher leaders, undergraduates as tutors for neighboring school districts, mentoring to support new teachers, specialized symposium for administrators, focus on curriculum assessment and implementation, LASER		
	IHE	x	Higher education science faculty develop year-long science course sequence for future elementary teachers	New	Elementary education major curriculum revisions	Professional development for faculty provided to build capacity in science education research methods and applications		

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Penn Science Teacher Institute	Pre-Serv						x	
	In-Serv	x	Developed 14 courses in integrated science (math, physics, environment, chemistry)	New		Master of Integrated Science Education program designed for current middle level science teachers, Master of Chemistry Education program designed for current high school science teachers		
	IHE							
Preparing Virginia's Mathematics Specialists	Pre-Serv						x	
	In-Serv	x	Numbers and Operations, Geometry and Measurement, Education Leadership I	New		Master's degree and certification as a math Specialist		
	IHE							
PRISM	Pre-Serv					Bridge Institute	x	
	In-Serv	x	Math endorsement courses, math and science courses	Both	Revised 6th grade math curriculum	PD-K-12, LC, endorsement on teaching certificate		
	IHE	x				Faculty rewards		

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Project Pathways	Pre-Serv						x	
	In-Serv	x	Developed 4 courses to meet 12 hours of the course requirements for a master's degree for secondary mathematics, physics, chemistry, biology, and geology teachers	New		Alternative certification program SCISM (Summer Certification in Secondary Mathematics) to recruit current mathematics majors to become certified to teach secondary mathematics		
	IHE	x	PHY 590: focus more on effective teaching strategies and practices and de-emphasize the study of physics education research; PHY 598: establish a graduate-level physics education seminar for in-service high school math and science teachers, STEM faculty, and STEM graduate students	New				

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Puerto Rico MSP	Pre-Serv	x	Teaching with technology workshop	New		Future Teachers Induction and Certification Component (FTIC), Assistant Capacitators Program, Mentors' Academy, summer research projects	x	
	In-Serv	x	Certification courses, math and science advanced courses, online courses in physics, math, and chemistry	New	Publication of training materials and curriculum implementation	Certify in-service teachers, Corporation for the Support and Education of the Community, "Authentic Professional Development Program" (APDP), summer professional development, summer camps for 6th-12th grade students. residential academy professional development program, learning communities		
	IHE	x	Developed 2 environmental science courses	New	Revised General Chemistry Laboratory			
Revitalizing Algebra	Pre-Serv	x	Field study course, Math 375, Math 700, capstone course, three-week all day summer institute, forum for issues of race, class, and ethnicity that can inhibit the learning of mathematics				x	
	In-Serv	x		New				
	IHE	x		New				

Table 4 (cont.): Detailed Profile of Changes in Selected MSPs

MSP	Audience		Types of Changes				Primary Focus	
	(Pre-Serv, In-Serv, IHE)		Courses		Curriculum	Programs (professional development, certificates, workshops)	K-12	IHE
			Subject	New/Redesign				
Rocky Mountain	Pre-Serv						x	
	In-Serv	x	Biology, Chemistry, ESS, Math (4)	New		Summer program, certificate program		
	IHE	x				Center for math and science and environmental ed, summer science camp (high school and STEM students)		
SCALE	Pre-Serv	x	General psychology course for all elementary education majors, content specific course in the secondary education program (both embed the "Principles of Learning")	New		SCALE Middle School Science Conference Disciplinary Literacy (DL) Mathematics and Science Institutes IFL Institute for Learning/SCALE In-District Work Urban Mathematics Leadership Network (UMLN) Content-Pedagogy Modular Learning Units CSUDH Summer Institute	x	
	In-Serv							
	IHE	x	Biology, Physics, Math, Chemistry (courses designed to attract STEM majors into K-12 teaching careers)	New				
VIP K-16	Pre-Serv							x
	In-Serv							
	IHE	x	Biology (gen ed), Chemistry (gen ed), Introductory Geology	Redesign	Lab course/activities	Physics faculty learning community, ExPert high school teachers summer visiting researcher program		

Appendix B

MSP-MIS Analysis of Higher Education Faculty Rewards and Responsibilties

Prepared by Danielle Susskind and Jennifer Frank
Change and Sustainability in Higher Education (CASHÉ) Project

July 2006

The MSP-MIS (Management Information System) is an online data collection system that is part of a comprehensive strategy for evaluation, research, and dissemination on MSP projects. It consists of a series of annual surveys for each type of MSP project, including the *Annual Survey for Comprehensive and Targeted Partnership Projects, Annual K–12 District Survey, Annual IHE (Institution of Higher Education) Survey, Annual IHE Participant Survey, Annual Survey for Institute Partnership Projects,* and *RETA Survey*. These surveys are developed, administered, and analyzed by WESTAT and sponsored by the National Science Foundation. Their purpose is to describe and provide longitudinal data in such areas as scope and coverage of the partnership, activities undertaken, and progress in the five key features for MSPs.

The *Annual Survey for Comprehensive and Targeted Partnership Projects* includes a series of open-ended questions pertaining to "Institutional Change and Sustainability" activities during the previous school year. Two of these survey questions address topics that are related to the goals of CASHÉ, including higher education faculty rewards for MSP participation and faculty responsibility and accountability for MSP project goals.

Faculty Rewards

The first survey question of interest pertaining to faculty rewards is the following:

Describe any new practices or policies that your IHE partners implemented during the last school year to reward IHE STEM faculty for (a) strengthening their own teaching practices, or (b) participating in K-20 teacher preparation and professional development programs.

Open-ended narrative responses to this question were summarized and placed into one of five categories that were developed by CASHÉ based on the themes that emerged from the data, including promotion, tenure, and merit policies; workload and monetary incentives; recognition opportunities; changes to institutional infrastructure; and professional development seminars and workshops. These categories are included in the table below along with corresponding strategies and examples cited by individual MSP projects.

During the first round of data collection in 2003-2004, 8 of the 35 participating MSP projects (23%) responded "none" or "not applicable" when answering this question. During the second round of data collection in 2004-2005, 9 of the 41 participating MSP projects (22%) responded "none," "not applicable," or "no new policies." One MSP project noted that faculty rewards were a "low priority" during both years of the survey.

The figures in parentheses denote the number of MSP projects that provided that particular response to the question. Since projects were assured of the confidentiality of their responses, names were removed from this version of the survey results.

THEMES/CATEGORIES	STRATEGIES/EXAMPLES
Promotion, Tenure, and Merit Policies	Consider faculty participation as a factor for promotion (6) Consider faculty participation as a factor for tenure (3) Consider faculty participation as a factor for merit (2)
Workload and Monetary Incentives	Provide course release/buyout for participation (4) Pay summer stipends or full faculty salary during the summer (4) Reallocate faculty workload/incorporate partnership responsibilities into workload (3) Provide tangible resources such as laptops, lab equipment, calculators, and departmental supplies (3) Pay overload stipends for faculty participation (2) Provide undergraduate student support for participating faculty members (1)

THEMES/CATEGORIES	STRATEGIES/EXAMPLES
Recognition Opportunities	Establish formal faculty awards programs (3) Enact faculty recognition policy (1) Provide recognition to faculty in newsletters and other publications (1) Promote faculty partnership work as "best practices" (1) Provide formal leadership roles for participating faculty (1)
Changes to Institutional Infrastructure	Create and support new STEM academic units/centers (2)
Professional Development Seminars and Workshops	Offer professional development seminars and workshops for STEM faculty (6)

Faculty Responsibility and Accountability

The second survey question of interest pertaining to faculty responsibility and accountability is the following:

Describe any new practices or policies that your IHE partners implemented during the last school year to encourage IHE STEM faculty to take responsibility and accountability for MSP project goals.

Again, open-ended narrative responses were summarized and placed into categories that were developed by CASHÉ. The same five categories that emerged in response to the faculty rewards question also emerged in response to the faculty responsibility and accountability question. In addition, the responses to this question suggested the addition of two additional categories: course/program creation and redesign and opportunities for professional collaboration. These seven categories are included in the table below along with corresponding strategies and examples cited by individual MSP projects.

In general, the responses to this question revealed that project leaders held a wide range of perspectives on faculty engagement in MSP activities. These three quotes (each from a different project) provide a sense of the diversity of opinions on this topic:

"Personal effort more than policy changes or rewards drive the faculty."

"Engagement springs from their (faculty) role in planning, decision-making, and monitoring a major component of the project."

"It will be a confluence of policy initiatives from the national level, the state level, the system-wide level, and the local IHE level that will contribute to lasting institutional change in faculty engagement in this work."

During the first round of data collection in 2003-2004, 13 of the 35 participating MSP projects (37%) responded "none" or "not applicable" when answering this question. During the second round of data collection in 2004-2005, 24 of the 41 participating MSP projects (59%) responded "none, "not applicable," or "no new policies."

THEMES/CATEGORIES	STRATEGIES/EXAMPLES
Promotion, Tenure, and Merit Policies	Consider faculty participation as a factor for merit (5) Consider faculty participation as a factor for tenure (4) Consider faculty participation as a factor for promotion (3) Consider participation for early tenure and promotion decisions (1)
Workload and Monetary Incentives	Revise faculty workload policies to include partnership work (3) Provide faculty release time (3) Pay faculty stipends for participation (3) Provide non-compensation financial incentives such as dedicated staff, materials, and technology (2) Hire new faculty with the understanding that part of their workload is tied directly to MSP activities (1)

THEMES/CATEGORIES	STRATEGIES/EXAMPLES
Recognition Opportunities	Offer faculty appointments to leadership positions with permanent institutional funding (1)
Changes to Institutional Infrastructure	Create Math and Science Outreach Center to coordinate partnerships and pilot initiatives to increase the number of college eligible ethnic minorities; has become the central point for new and veteran faculty to create and administer outreach programs (1)
Professional Development Seminars and Workshops	Offer STEM faculty seminars and workshops – unspecified content (5) Develop faculty training on state-level STEM standards (1) Conduct sessions with faculty on improving inquiry-based teaching methods to replace traditional lectures (1) Host retreat for full-time STEM faculty to discuss how to increase student engagement (1) Develop and offer required programs on teaching and assessment for new STEM faculty (1) Organize statewide faculty institutes (1)

THEMES/CATEGORIES	STRATEGIES/EXAMPLES
Course/Program Creation and Redesign	Provide opportunities for college faculty and K-12 teachers to co-develop and/or co-instruct courses (5) Offer new or modified higher education courses developed by MSP faculty participants (4) Use project evaluation data for higher education course revisions and improvements (3) Provide opportunities for STEM and education faculty to co-develop and co-instruct courses (2)
Opportunities for Professional Collaboration	Convene regular meetings of cross-institutional MSP leadership team (2) Create faculty and teacher research teams (2) Convene regular campus-wide meetings involving MSP leaders, department chairs, and faculty focused on developing a greater understanding of MSP goals and activities (1) Create P-16 committees with representation from university leadership (1) Facilitate cross-campus faculty visits (1) Establish campus committees with both STEM and education faculty (1) Formalize STEM faculty involvement in teacher education programs (1) Promote better articulation between community colleges and universities in course alignment and transfer policies (1)

Appendix C

MSP Learning Network Conference Report
Engaging STEM Faculty in MSP: Promises and Challenges
Washington, D.C.
January 26-27, 2007

Jennifer Frank & Nancy Shapiro
Change and Sustainability in Higher Education (CASHÉ)

Introduction and Framing the Questions

On January 26-27, 2007, the National Science Foundation hosted its fifth annual Math and Science Partnership (MSP) Learning Network Conference in Washington, D.C. The theme of the conference was *Engaging STEM Faculty in MSP: Promises and Challenges.* This annual forum provides opportunities for all 48 MSP and RETA (Research, Evaluation, and Technical Assistance) projects to come together to share information, tools, and resources; network and connect with each other; and disseminate best practices and findings. This year's conference was attended by approximately 300 participants, with broad representation from STEM (science, technology, engineering, and mathematics) faculty.

Past conferences have focused on other themes related to the key features of NSF's MSP program, including challenging courses and curriculum; partnerships; evidence-based decision making in MSP work; and teacher quality, quantity, and diversity. This year's emphasis on the engagement of higher education STEM faculty provided particularly important insights into MSP work because of the double systemic challenge of integrating college faculty with K-12 public schools, and STEM faculty with education faculty. Given the large numbers of faculty involved across the country and the diverse range of roles and responsibilities they fulfill, this MSP meeting in particular targeted a critical set of issues that address the overall success of the MSP program.

Because MSP work represents a departure from the traditional roles of most STEM faculty, it provides a unique lens for examining the related issues of institutional support, recognition, and rewards for such work as well as aspects of institutional culture that present both opportunities and challenges for individuals who engage in it.

The opening remarks by Dr. Diane Spresser, NSF's senior program coordinator for MSP, provided the context for the focus of the conference, described as exploration into the who, the what, the why, and the how of STEM faculty engagement in MSP projects. She explained, "It's about the promise of what might be if STEM faculty and higher education really take to both heart and mind the importance of high quality mathematics and science for all students at all grade levels, and respond accordingly. But it's also about the challenges they face in their higher education environments, if they actually do that."

The agenda of the conference encompassed a range of presenters and topics, including

- plenary sessions delivered by college presidents who have MSPs on their campuses;
- the external policy landscape from the perspective of NSF and the U.S. Department of Education;
- presentations on faculty engagement;
- facilitated discussions on challenges, strategies, and sustainability; and
- structured breakout sessions in which individual projects shared and disseminated their work.

This report attempts to capture and summarize the knowledge and findings that were shared about STEM faculty engagement during the conference. It draws upon the analysis of session transcripts, meeting notes, and presenter materials. It is not intended to be an encyclopedic conference report. Rather, its purpose is to provide an analysis of key learnings filtered through the lens focused on STEM faculty engagement.

This summary begins with an overview of the characteristics and effects of higher education faculty who are involved in MSP projects, the role of institutional leadership, and the broader political and social context in which MSP work occurs. It continues with a synthesis of discussions (in which all conference attendees participated) surrounding the promises, challenges, and sustainability of faculty engagement. The report then presents promising models for faculty engagement across projects, perspectives from STEM faculty members, and conceptual approaches for studying faculty engagement and MSP impact. It concludes with a summary of cross-cutting issues and themes.

Defining Faculty Engagement in MSPs

Dr. Joy Frechtling and Dr. Xiaodong Zhang of WESTAT presented a session titled "IHE Faculty Engagement in MSP: A Profile," which summarized demographic characteristics of participating faculty nationally and presented information on the nature, scope, and impact of their involvement in MSP projects. Sources included the MSP Management Information System (MSP-MIS), which projects use for annual reporting, and data collected via site visits, interviews, and secondary data analysis through WESTAT's RETA project titled "Effect of STEM Faculty Engagement in MSP."

During the 2005-06 academic year, a total of 1,122 faculty participated in MSPs across the country – 61% from STEM, 25% from education, and 14% from other disciplines. Of this total, 55% were from doctoral-granting institutions, 52% were tenured, and 25% held the rank of professor. Approximately one-third of the participating faculty had not been involved in any previous K-12 educational reform efforts prior to MSP. Among the STEM faculty participants, 29% indicated that they had spent more than 200 hours on

MSP activities during the academic year; while approximately 50% of the STEM faculty had been engaged 80 hours or more. In addition, 22% of the mathematics faculty and 17% of the science faculty were conducting some form of educational research. At the same time, only 9% of STEM faculty reported that they had participated in the development of policies on their campus to reward faculty for their involvement in K-12 education.

During this same academic year (2005-06), STEM faculty members were most frequently involved in activities targeted toward pre-service teachers, in-service teachers, and K-12 students. For pre-service teachers, 25% of STEM faculty were involved in teaching or co-teaching pre-service STEM content courses, and 21% were involved in mentoring pre-service students. For in-service teachers, 61% of STEM faculty conducted workshops, institutes, and/or courses to increase teacher content or pedagogical knowledge, 51% were "on-call" for classroom teachers, and 37% conducted targeted workshops, institutes, and/or courses. For K-12 students, 29% of STEM faculty were involved in the alignment of K-12 curricula to other courses and standards, and 29% participated in initiatives to motivate student participation in challenging STEM courses. Among the first cohort of MSP projects, the average number of activities that STEM faculty members participated in actually decreased over the past four years with respect to these three categories of involvement, with the average number of faculty activities for pre-service teachers being 1.6 (versus 2.3 in 2002-03), for in-service teachers being 2.7 (versus 3.0 in 2002-03), and for K-12 students being 1.1 (versus 1.6 in 2002-03).

This latter finding (decreased faculty activities) was somewhat surprising to several conference participants and was discussed as an area for further investigation during the presentation. One explanation offered is that many STEM faculty were initially involved in designing new courses and curricula for MSP, which have now been implemented and taught several times, and thus are no longer recorded as finite "activities" when faculty report on their MSP involvement.

WESTAT also studied the phenomenon of "STEM effects" across eight different MSP projects in order to gain an understanding of the ways in which STEM faculty members are involved in MSPs and the impact of their engagement on K-12 teachers, students, themselves, and their institutions. The researchers examined the multiple roles that faculty play in MSPs, including pre-service work (teaching content courses, curriculum design, student recruitment, mentoring), in-service work (working in teams, delivering content, delivering pedagogy), project management, and research. Among their central findings were that faculty relationships with fellow faculty colleagues and other key players were critical to the success of these projects. At times it was just as challenging for the STEM faculty to work with each other as it was for them to work with teacher education faculty and K-12 teachers, but mutual respect and ongoing communication helped facilitate their success. The research team also found continuing evidence of change in practices and attitudes among STEM faculty and the ways in which they considered their roles in teaching and instruction. Many participating faculty cited increases in their pedagogical knowledge as a result of their involvement in MSPs as well as increases in understanding the K-12 perspective.

The researchers cited evidence that MSP projects are encouraging, recognizing, and rewarding STEM faculty participants through both extrinsic and intrinsic rewards. The extrinsic rewards were primarily monetary in nature including stipends, release time, and other forms of compensation. The intrinsic rewards included targeted and ongoing recruitment of faculty, opportunities for professional development, opportunities for faculty to develop niches and areas of expertise, communication, and sensitivity to faculty needs and time.

Key Findings: The researchers found limited evidence for actual institutional policy changes to encourage and reward this type of work, acknowledging that existing rewards structures and culture often serve as barriers to STEM faculty engagement. They observed that MSP participation is generally characterized as faculty outreach and service, rarely as scholarship, and is considered a distant third priority to research and teaching. In addition, junior faculty members were frequently discouraged from participating in MSP-type work.

The site visits facilitated the definition of a common set of elements and characteristics among participating higher education institutions with high STEM faculty involvement in MSPs. The researchers found that these campuses had a "policy-friendly" environment with institutional and structural supports in place for STEM faculty, paying attention to the sustainability of these efforts over the long term. They cited that the central players in the project had a high profile on campus and that a critical mass of STEM faculty were involved rather than a few outliers, their work representing true collaboration rather than isolated efforts. In addition, STEM faculty on these campuses played key leadership roles in the instruction of MSP courses and programs.

Reflections on the Role of Institutional Leadership

The conference keynote addresses were delivered by two university presidents with MSPs on their campuses, Dr. Freeman A. Hrabowski III, President of the University of Maryland Baltimore County (UMBC), and Dr. Diana Natalicio, President of the University of Texas at El Paso (UTEP). UMBC serves as the lead partner for a comprehensive MSP and is a core partner for a targeted MSP, which is lead by the University System of Maryland. UTEP is home to the El Paso Math and Science Partnership, a comprehensive MSP. In their remarks, Dr. Hrabowski and Dr. Natalicio both addressed their commitment to MSPs and STEM, the engagement of faculty in these initiatives, challenges and barriers to institutional change, and the crucial role that leadership plays in supporting and sustaining this work over time.

Reflections from the University of Maryland Baltimore County

According to Dr. Hrabowski , a major challenge to promoting STEM education reform – encouraging STEM students to enter teaching and increasing collaboration with K-12 schools – is that the higher education community at large tends "not to see the work of involvement with K-12 as intellectually respectable or important enough to be considered

part of the reward system." While this assessment may sound harsh, it rings true to the broader higher education community. Unless and until that underlying perception changes, the MSPs and the communities they represent will continue to struggle for appropriate recognition.

A second challenge for the MSP vision is the prevailing attitude among higher education faculty and administrators that high-performing STEM students should be pointed in the immediate direction of the Ph.D. and steered away from K-12 teaching, prompting Hrabowski to ask, "Who do we really think should be teaching math or science, in some cases engineering, in the K-12 system? And why do we believe that people should have a certain type of background?"

Dr. Hrabowski raises a very good question: Who *do* we think should be teaching math or science? Is it a fallback option for "second raters?" Or, is it among the most honorable of professions? And whose responsibility is it to (re)establish the elevated perception of teaching? Clearly, Dr. Hrabowski is raising critically important and provocative questions that go beyond the MSP community. His purpose, it would appear, is to elevate the call to the public forum, charging the MSP community to take the leadership in raising the issue to the broadest policy levels.

In addition to combating attitudes that often steer interested students away from K-12 teaching, Dr. Hrabowski also pointed to the fact that substantial numbers of first-year college students do not succeed in their STEM courses and end up departing STEM majors prematurely for other disciplines. And, even among those STEM students who do persist to graduation, large numbers decide to pursue alternative professions. He stressed that campuses must first have a series of campus conversations about how students are performing during the first year of STEM coursework, the factors behind these issues, and how this relates to their prior K-12 preparation. Collect the data – analyze the evidence. But he challenged the group not to stop at the "conversation" level. What are we going to do about it? He emphasized the importance of connecting K-12 involvement to undergraduate teaching and learning itself, not seeing these as two separate issues.

Dr. Hrabowski stressed that campuses need to validate the importance of this work and those involved in it, acknowledging that it is not going to be the right fit for every faculty member. At the same time, he spoke about the central role of STEM faculty in the success of MSPs and other P-16 partnerships, stating: "The most powerful people on any campus will be its faculty … Nothing of substance happens on a campus that they don't believe is important." While such campus leaders as the president, provost, and deans can set the tone, provide recognition, develop new rewards structures, the more STEM faculty who are involved, the more prestigious the project becomes.

Dr. Hrabowski challenged higher education institutions by posing the following questions:

- What is your campus's attitude, broadly, with regard to involvement with P-16 work?
- How much time do people spend discussing the issues?
- What people?
- How often are there public campus conversations about the challenges involved in this work?
- To what extent has the campus thought about hiring people with additional expertise?
- Are there opportunities for rewards or recognition as a result of that work?

Dr. Hrabowski urged that campuses leaders need to systematically collect information about STEM faculty involvement in high schools, middle schools, elementary schools, and with teacher education, both because they may be unaware of the extent of P-16 and STEM activity, and because they need data to establish benchmarks and goals. For example, UMBC has moved to an institutionalized practice of including a section for P-16 involvement in faculty annual reports, which sends an important message to the university community that this work is a priority. He also stressed the importance of carving out well-defined roles for STEM faculty in these projects – with a commitment to specific responsibilities and activities – since faculty may not know how to get involved or best utilize their expertise. The notion of faculty rewards is also important – the fact that individuals appreciate being recognized for what they do. And, while the amount of available funds for merit pay may be limited, it does send a message and resonates as a prestigious form of recognition for some. In addition, the more that the campus community hears about P-16 work and realizes that it is an institutional priority, the more weight and prestige it carries.

Dr. Hrabowski also pointed to structural changes within universities that can support MSPs and P-16 work and that promote the institutional sustainability of these initiatives. For example, UMBC created a Center for STEM Education to focus the efforts of the campus. In addition, UMBC transitioned an "engineering education" faculty member from a non tenure track position to a tenure track position, sending a message that this faculty member's area of expertise was a valued and important investment to the institution. He also discussed the importance of vigorous fundraising and campaigns to support P-16 outreach and related efforts, since this work often tends to be supported by individual grants that come and go over time.

Finally, Dr. Hrabowski stressed the importance of encouraging faculty who are involved in MSPs and other P-16 initiatives to conduct research and evaluation on this work and to disseminate it through publications. He acknowledged that these types of research questions push the envelope of "acceptable" research in most STEM departments, but he

challenged the MSP community to push that envelope with respect to tenurable research agendas. Expanding the range of creditable peer review activities may require the involvement of institutions and other disciplines with specific expertise in STEM education research, particularly when this expertise exists in a limited capacity on the home campus, but that is part of pushing the envelope.

Reflections from the University of Texas at El Paso

In her remarks, Dr. Natalicio traced the process as UTEP "changed from a small and rather isolated institution into an institution that understands its region, its mission, and its service in a way that we didn't before." She described how UTEP faculty members in the early 1990s had been increasingly dissatisfied with the academic preparation of students who were coming into the institution. At the same time, UTEP's student demographics did not mirror the demographics of surrounding El Paso County, in spite of the fact that 82% of these students were from the immediate area. Rather than become increasingly isolated, the institution made the conscious and strategic decision to integrate itself more fully into the community, and thus, the El Paso Collaborative for Academic Excellence was born. This partnership, now over a decade old, involves UTEP, El Paso Community College, local school districts, and civic and business leaders, who were particularly interested because the region's economic development, relying on low wage, low skill labor, rested on a premise that was no longer sustainable.

Dr. Natalicio shared that one of the most important understandings in getting the campus community on board with this new vision, particularly faculty, was in helping everyone realize that they were part of a "closed loop" system, as UTEP drew a majority of its students from the local public schools and produced approximately two-thirds of the K-12 teachers who were teaching those students. She noted that self-interest was a strong motivating factor, in helping faculty see that their involvement in K-12 schools would lead to better prepared students at the university. As she explained, "It's in my interest as a faculty member if I want good students coming into my classes and into my research labs, it's incumbent upon me to help the schools and to work closely with them in aligning curriculum and all the other kinds of things we're doing. I have to have that interest. I have to be engaged."

Dr. Natalicio was passionate about faculty responsibility for building the pipeline – if higher education is not committed (they are, after all, the most direct and proximate beneficiary of good students), why should anyone else care? At the same time, she stressed that such engagement was not a unidirectional activity: not only should university faculty bring their expertise into K-12 classrooms, but K-12 teachers should be invited to share their pedagogical expertise with faculty.

One of the major challenges to fully embracing this work from a leadership perspective, Dr. Natalicio shared, is that colleges and universities that are not at the top of the "prestige heap" are often risk-adverse. More specifically, asking faculty who are trying to build a national reputation for themselves to get involved in an activity that does not further their personal or institutional prestige takes a leap of faith. Thus, it is important

for the president and other institutional leaders to stress that community engagement is a prestigious niche for a university like El Paso, one at which it could excel and be at the national forefront, and one that could benefit them all.

Dr. Natalicio asserted that college and university leaders need to send, frequent, clear, and consistent messages about MSPs and similar initiatives so that faculty members do not receive mixed signals about fundamental institutional priorities. She discussed the importance of recruiting faculty who understand from the very beginning what the university's expectations are all about, from the initial campus interview through the hiring process and new faculty orientation. Institutional leaders must reiterate this message time and time again, through such opportunities as university convocations, faculty senate, board of regents and university system meetings, and talks with civic organizations, members of the state legislature, national policymakers, and the corporate sector.

Like Dr. Hrabowski, Dr. Natalicio emphasized that MSP projects need to create specific roles and "unobstructed pathways" into the K-12 schools for faculty members, as this can often be a new and unsettling experience for them. She also stressed the importance of ensuring that participating faculty members are highly visible and recognized. She explained, "We try very hard to give them high visibility, to make them highly noted on the campus, to make them our heroes, to make them the people that we validate, who validate the concept of the partnership." She also talked about the importance of mobilizing the efforts of other administrative areas within the university, including the financial aid and development offices, to raise additional funds to support this work. Faculty members should feel assured that the entire institution is behind their efforts, "Not just to validate them in word, but in deed."

Reflections on the National MSP Context

Reflections on the broader context of MSPs were offered by three speakers, all leaders in the national policy arena, including Dr. Arden Bement, Director, National Science Foundation; Dr. Cora Marrett, Assistant Director Designate, Directorate for Education and Human Resources, National Science Foundation; and Dr. Raymond Simon, Deputy Secretary, U.S. Department of Education.

Dr. Arden Bement, Director, National Science Foundation

"In a highly mobile society, education has few boundaries and an open-ended timeframe. Partnerships must be formed that work across all sectors to synergize and maximize the gain from our respective efforts."

Dr. Bement focused his remarks on several promising outcomes from MSPs thus far resulting in continuous improvements in student achievement and proficiency, including developments cited in the *MSP Impact Report*, released in January 2007. In particular, he noted documented improvements in student achievement at the elementary level and in mathematics. He applauded the far-reaching impact of MSP programs, which are

expected to involve over 136,000 mathematics and science teachers in total, with MSP-sponsored professional development programs reaching more than 30,000 teachers during the last academic year alone. He also stressed the importance of developing rigorous tools and metrics in order to evaluate the impact of MSPs and maximize NSF's potential for current and future investments in improving STEM teaching and learning. In keeping with the theme of the conference, Dr. Bement emphasized the importance of the role of STEM college and university faculty in MSP work – particularly in the alignment of courses, curricula, and standards between K-12 and higher education – creating a "seamless continuum of learning." He also noted the significant contributions that STEM faculty make when they use their own research and scholarship to help teachers and students understand how scientists think, use evidence, and conduct research.

Dr. Cora Marrett, Assistant Director Designate, Directorate for Education and Human Resources, National Science Foundation

"What are we learning about effective partnerships that can help foster the capacity to achieve excellence? How do we replicate effective partnerships? What constitutes effective change? How do we know if we are making progress?"

Dr. Marrett characterized the MSP program as a pivotal feature of the broader portfolio of change efforts at NSF – "a portfolio that aims to promote excellence." She described the importance of linking these various change efforts, both across individual partnerships and across individual funding agencies in order to ensure that resources are leveraged in ways to maximize outcomes for STEM education. She described the MSPs as "intellectual partnerships" – involving STEM faculty, teacher educators, teachers, administrators, and professionals in business and industry – building a community that is central to the "development of ideas and institution of changes." Dr. Marrett cited the need for improved interchange and integration of experiences, ideas, and goals through the MSPs and similar programs, which she likened to the process of research and discovery. Like Dr. Bement, she stressed the importance of documenting successes, failures, and other understandings that have come out of MSPs through rigorous evaluation and assessment strategies.

Dr. Raymond Simon, Deputy Secretary, U.S. Department of Education

"I am absolutely in your corner when saying [down with] any barriers we have to allowing quality professionals, I don't care if they're college professors, if they're doctors, if they're scientists, whatever they are. If they have a skill and are willing to teach and can teach, I want them in the public school."

Dr. Simon described current initiatives at the U.S. Department of Education, including Math Now, ACI Smart Grants, and the Teacher Incentive Fund, which are designed to support goals similar to MSPs through improving STEM teaching and learning and expanding opportunities for students and teachers. He highlighted areas of progress from No Child Left Behind (NCLB), particularly in reading, writing, and mathematics in the early grades, and stressed that similar levels of rigor need to be moved into middle and

high schools. Dr. Simon emphasized the importance of removing barriers to placing high quality teaching professionals in the classroom, including non-traditional candidates. He candidly and directly addressed the unfortunate reality at some institutions of higher education where barriers exist between education and STEM faculty. He stressed that faculty from colleges of education must work more closely with STEM faculty, and that STEM faculty must respect the knowledge and expertise of their education colleagues. He also suggested that K-12 and higher education need to move beyond their distrust of each other in order to move the STEM agenda forward. Programs like MSP are gateway projects that will lead to greater collaboration and expanded learning opportunities for students and teachers.

All three of these speakers demonstrated a commitment to the central goals of the MSP program: improving student achievement in mathematics and science; investing in high quality, aligned curriculum and courses; outreach to a broad and diverse range of schools, school districts, teachers, faculty, universities, and colleges; evidence-based decision making; and engagement of college and university faculty in the real work of teaching science and mathematics P-16.

All three speakers clearly value the investments made in partnership activities, but all are aware that partnerships are still "unnatural" acts, given the current culture of schools and universities. The overarching conclusion that can be drawn from these three speakers, with their different perspectives, is that the MSP work is not just important, but essential to meeting the challenges of the 21st century. They each acknowledge that there is much hard work going on across the projects. But, to quote Tom Hanks, playing the crusty manager of a women's baseball team in the movie *A League of Their Own*: "It's supposed to be hard. If it wasn't hard, everyone would do it. The hard is what makes it great."

The Nature of MSP Faculty Engagement: Promises, Challenges, and Sustainability

During the first day of the MSP Learning Network Conference, 16 breakout discussion sessions were held involving two to five projects in each group. Comprehensive, targeted, and institute projects were grouped together for a series of facilitated conversations about major challenges to faculty engagement, strategies to overcome these challenges, and the sustainability of faculty engagement beyond the life of the MSP grants. The major themes that emerged from these discussions were the following:

- A common initial selling point for STEM faculty involvement in MSP is altruistic and outreach-oriented: their interest in helping to support K-12 teachers and improve K-12 education. For many faculty, however, their involvement transforms into something deeper and more meaningful over time. Faculty realize that they have an opportunity to learn from what K-12 teachers have to offer about teaching, and they often strive to improve their own courses and pedagogy beyond the scope of their MSP responsibilities. They also realize that through work on P-16 curriculum alignment issues, they can have a positive impact on the academic preparation of future students coming to their university. Through their involvement, STEM faculty

are often surprised by the complexities of the K-12 educational system, approaching their MSP work like they would approach a problem in science.

- It is important to create concrete, specific roles for STEM faculty involvement in MSP projects and to differentiate these roles in order to attract faculty with diverse interests and talents. Projects need to be specific about anticipated time investments and responsibilities. In addition, they need to be sensitive about the use of faculty time and find strategic ways to get them involved, as faculty often state, "We don't know how to get involved." Faculty often have a high learning curve with respect to this type of work if they have not done it previously, and it may be too challenging or frustrating for them if given a role that is open-ended and undefined. Institutions should ask themselves, "How do we best capitalize on the human resources of our faculty?" Some faculty will do well on the front lines working with teachers and faculty members from other disciplines in MSPs, while others will not. However, appropriate recognition needs to be given for all of these different roles that faculty members can play.

- The relationship-building that occurs among STEM faculty, education faculty, and K-12 teachers builds an important foundation for sustainable collaboration beyond the life of these grants. However, while sustainability may be achieved on certain levels among individuals who participated in the MSPs (e.g., changes in pedagogy or increased content knowledge), this may not necessarily translate to the institutional level without formal structures behind it. Sustainability is not going to happen naturally without significant investments for change.

- Projects should consider how to engage STEM graduate students in this work more systematically, viewing their involvement as a form of "pre-service" training for future university faculty. In terms of broader outcomes, to what extent have MSPs had an impact on the pipeline of future STEM faculty?

- The MSP community should continue to promote faculty engagement in the research and scholarship of STEM teaching and learning. This is an ongoing challenge, however, because educational research is not necessarily recognized in traditional STEM rewards structures.

- In addition to faculty buy-in and ownership, institutional leadership is crucial to bringing about sustained change in faculty engagement and higher education, especially in recognizing faculty for their contributions, influencing reward structures, and supporting permanent institutional structures for housing this work (e.g., joint appointments, STEM Centers for Teaching and Learning, etc.).

- It is important to recognize that change in higher education can be "slow and glacial" and that the impact of MSPs may not be felt for some time, especially when outcomes are not immediately recognizable or tangible. As one project member shared, "Many of us expected to see this miraculous change that just didn't happen." New courses or programs are an obvious measurable outcome, but what else? Also, the notion of

"culture change" in higher education is not always well-defined or well-articulated. What changes do we really want to see? Can STEM culture actually change? What is the appropriate amount of time in which to anticipate significant changes at the university level?

Models of MSP Faculty Engagement from the Field

The MSP Learning Network Conference included a series of concurrent breakout sessions over the three days of the conference. Facilitated by project directors, faculty, teachers, administrators, researchers, and other members of the MSP community, these sessions formed the heart of the conference by providing a public forum to share knowledge and experiences and various aspects of current MSP work. Breakout sessions focused on the theme of the conference, STEM faculty engagement in MSP, and addressed topics including: course and curricular innovations; collaboration between STEM and teacher education faculty; involvement in P-16 learning communities; and institutional policy developments to support and reward STEM faculty. Taken together, these sessions provide important insights into the nature and scope of faculty involvement across MSP projects through concrete examples from current projects.

One of the unexpected observations that can be made about these sessions as a whole, is that while they were developed as primarily traditional presentations to share work in progress and evidence-based findings, in fact, the overwhelming impression communicated by the sessions was a startling realization by STEM faculty of the rich learning opportunities that MSPs create for these faculty members as they consider their own teaching and pedagogy.

Several typical examples that were shared during the breakout sessions are summarized in the table below. Six major categories of STEM faculty involvement emerged:

Collaboration with K-12 Teachers

- STEM faculty from the SCALE project, along with science expert teachers from the Los Angeles Unified School District, work collaboratively in the co-development and co-facilitation of professional development programs as well as new teaching units for K-12 classrooms. Faculty report important impacts on their own professional development in a number of areas, including new working relationships with K-12 teachers and teacher education colleagues, revised pre-service content courses, increased knowledge of inquiry, expansion into non-lecture pedagogies, deepened understanding of student learning styles, and interest in advocating for policies that increase pre-service teacher exposure to STEM.

- STEM faculty from the MSP of Southwest Pennsylvania work with K-12 Teacher Fellows, on sabbatical from their school districts, to review and revise undergraduate mathematics and science courses, as well as education courses.

- Faculty in the Appalachian Mathematics and Science Partnership (AMSP) are involved in partnering with K-12 teachers to develop pre-service courses in mathematics and science, design in-service professional development, and implement a series of regionally-based Partnership Enhancement Projects (PEP) with local school districts.

Collaboration with Teacher Education Faculty

- Auburn University has held a series of on-campus seminars to develop a common vision for teacher pre-service and in-service education among mathematics education faculty and STEM faculty members involved with the TEAM-Math MSP. These sessions have focused on such issues as pedagogical knowledge of teachers, curriculum reform, and content courses.

- The Rocky Mountain Middle School Math and Science Partnership provides courses to teachers in several school districts in the Denver metropolitan area. Each is team-taught by a STEM faculty member, education faculty member, and K-12 teacher. As a result of their participation, STEM faculty have reported a deepened understanding of students coming into their classrooms, an increased interest and willingness to try new instructional techniques and approaches in their other STEM courses, and an increased respect for the knowledge and expertise of their education and K-12 colleagues, including their content knowledge of the discipline.

Involvement in Professional Development

- STEM faculty involved in the Alliance for the Improvement of Mathematics Skills (AIMS PreK-16) provide professional development for both PreK-12 teachers and higher education faculty on such topics as understanding the state's mandated mathematic skills. They conduct teacher observations, consult on course sequencing, serve as mentors for teacher support, and participate in region-wide sessions on mathematics achievement, among other activities. Preliminary findings indicate that student achievement has increased among teachers who have participated in these professional development offerings.

- Faculty members involved with the Math and Science Partnership of Greater Philadelphia (MSPGP) participate in monthly pedagogy seminars with middle school and high school teachers to focus on advances in learning theory and formative assessment. They apply these new techniques in their classrooms and report back on their experiences. Faculty report that they continue to use these new approaches in their instruction, even after completion of the seminar.

- Through the MSP of Southwest Pennsylvania, participating faculty learn about inquiry-based and standards-based instruction through their involvement in Teacher Leadership Academies each summer.

- University mathematicians, engineers, and teacher educators who are part of the Greater Birmingham MSP, participate along with K-12 teachers as learners during nine-day mathematics content courses. They report a substantial impact on their own instructional practices and their understanding of the K-12 context.

Involvement in K-12 Curriculum Reform

- Informed by AAAS and NRC science standards, Promoting Rigorous Outcomes in Mathematics/Science Education (PROM/SE) faculty have developed an organizational framework for the school science curriculum by identifying overriding themes that help children learn and teachers teach science better.

- Rather than using faculty expertise to teach more advanced or abstract topics, Revitalizing Algebra (REAL) has involved STEM faculty in facilitating work on rich problems that are accessible at the school algebra level but can be extended to deeper and more complex mathematical concepts.

Involvement in Learning Communities

- The Rice University Mathematics Leadership Institute brings together faculty, graduate students, and K-12 teachers in a coherent professional learning community through summer meetings and year-long follow-up support focusing on the development and teaching of challenging curricula by "doing mathematics as mathematicians do." Faculty are challenged to use collaborative learning rather than direct instruction, graduate students gain curriculum development experience by creating assessments and instructional materials, and K-12 teachers gain problem-solving learning experiences that are directly transferable to their mathematics classrooms.

- California State University, Fullerton faculty involved with Teachers Assisting Students to Excel in Learning Mathematics (TASEL-M) participate in professional learning communities with teacher leaders from low performing high schools and their feeder middle schools. Faculty and teachers work together to address pedagogy, content knowledge, and strategies to increase student motivation and achievement.

Involvement in P-16 Alignment Activities

- In the UMBC-BCPS MSP, STEM faculty, education faculty, and school district mathematics teachers and administrators have come together to examine student placement and performance data in mathematics courses at the University of Maryland Baltimore County in order to discuss how to fill critical gaps and build bridges between high school and college preparation and expectations.

Models of Institutionalization and Sustainability

In addition to the sessions dealing with specific strategies, approaches, and best practices for STEM faculty engagement, another strand of sessions focused on policy changes and structural innovations that support MSP faculty involvement and project sustainability.

The Case for Systemwide Policy Change: PRISM

The Partnership for Reform in Science and Mathematics (PRISM) in Georgia, for example, had Strategy 10, which was to "provide a reward structure in universities to encourage faculty members to sustain involvement in improving science and mathematics teaching and learning in K-12 schools." Through Strategy 10, PRISM partners were involved in the development and implementation of a new University System of Georgia "Work in the Schools" policy that advocated for higher education faculty involvement in and rewards for P-16 work. This new policy, approved by the Board of Regents, stated that "University System institutions that prepare teachers will support and reward all faculty who participate significantly in approved teacher preparation efforts and in school improvement through decisions in promotion and tenure, pre-tenure and post-tenure review, annual review and merit pay, workload, recognition, allocation of resources, and other rewards." Forms of "significant participation" for faculty include improving their own teaching to model effective pedagogical practices for prospective teachers, conducting research and scholarship to improve student learning both in K-12 schools and higher education, and collaborating with public schools in such areas as strengthening teacher quality and increasing student achievement.

The Case for Integrated Institutional Culture Change: SCOLLARCITY

Likewise, in the SCOLLARCITY MSP, there have been developments to institutionalize faculty reward and support structures at SUNY College at Brockport, with the principal investigator, Dr. Osman Yasar, stating, "Transparency in the appointment, promotion, and tenure (APT) process is important institutional support to sustain MSP activities among faculty." SUNY Brockport has set educational research, improvements to teaching and instruction, and community outreach as milestones for its APT guidelines. In addition, the SUNY System dedicated an Empire Professorship, a new faculty research line, to sustain the MSP work. The integration of MSP objectives into the institution's strategic plan, including the development of new courses and programs and the integration of technology into instruction, has also aided the institutionalization and sustainability of project efforts. All six of the participating junior faculty in SCOLLARCITY have received tenure, and all of the participating senior faculty have been promoted, even with changes in the presidential and dean leadership over the course of the five-year project, which, as stated by Dr. Yasar, " ... points to the power of the institutionalization of effective strategies."

The Case for Structural Change: Texas Middle and Secondary Math MSP

Still other projects cited structural changes and enhancements for their higher education institutions to support and sustain their MSP work, including Stephen F. Austin State University of the Texas Middle and Secondary Math MSP. This university plans to imbed the goals and objectives of its MSP into a campus-wide STEM Learning Center, which will research, develop, implement, and disseminate best practices in STEM education. The Center will also help faculty coordinate their efforts in creating interdisciplinary degrees, opportunities for project-based learning, and seamless alignment of the STEM curriculum P-16. The development of cross-cutting departments, centers, or units to engage faculty in this work is a strategy that has been used on a number of campuses in order to mobilize the campus community and help the campus institutionalize the efforts of MSPs and related P-16 initiatives.

Perspectives from STEM Faculty

Planners included a strand of "Job-Alike" breakout sessions as part of the conference. These facilitated discussions were designed to provide the opportunity for individuals with similar roles across MSP projects to get together to talk about topics of common interest and to have time for idea-sharing and consultation. They were also designed to provide feedback about how stakeholder groups are currently engaged in MSP work and their views on various aspects of their involvement with MSPs. A total of seven job-alike sessions were held: four for specific target groups (principal investigators, STEM faculty members, researchers/evaluators, and institute partners) and three for specific target topics (lesson studies, distance learning, and project sustainability).

The "Job-Alike" sessions for STEM faculty, facilitated by three current and former STEM faculty members, were particularly rich in personal insights into the experiences of STEM faculty in MSPs, including the following themes and observations:

Identifying specific roles for STEM faculty:

A recurring theme from faculty is the frustration of dealing with the bureaucracy of public schools. Carving out specific and tangible roles for STEM faculty in K-12 schools is critical to a successful and fulfilling P-16 collaboration, and a major source for increasing faculty recruitment and ongoing involvement in MSPs. One session participant described this process as providing STEM faculty with "their own lines into the school system." They shared that when they speak with fellow STEM faculty about getting involved in MSP work (or K-12 schools in general), their colleagues want to be directed toward specific roles and tasks rather than general activities, particularly since many have not been involved in work of this nature previously. So, for example, such responsibilities as "being available to K-12 teachers for consultation" are often not enough to encourage faculty to participate. One session participant cited that such formal structures as Professional Development Schools (or the equivalent), in which STEM faculty are responsible for such activities as delivering professional development

programs and teaching courses to pre-service and in-service teachers, can effectively facilitate STEM faculty interaction with the K-12 community.

Emphasizing the role of campus leadership:

Campus level leadership is critical to STEM faculty involvement – another recurring theme of the conference. Session participants noted that campus leaders have a central role in encouraging, rewarding, and supporting faculty involvement in MSP-type work. In particular, they emphasized the critical importance of STEM deans and department chairs to buy into this work, particularly since they are in positions to influence institutional policy (e.g., including these responsibilities in faculty contracts, changing the merit system to recognize and reward faculty involvement, legitimizing faculty research and scholarship that comes out of this work).

Campus leaders also play an important role by making decisions regarding resource allocation and the resulting institutionalization (or lack thereof) of P-16 type work in the definition of faculty roles and responsibilities. On some campuses, this has resulted in the creation of formal structures such as multidisciplinary STEM centers or K-12 partnership offices. One faculty member shared that his university had invested in the development of a new STEM laboratory that was designed to train teaching assistants (as the future professoriate) about STEM teaching and learning.

Taking joint ownership for STEM teacher preparation:

Session participants cited that as teacher preparation and certification programs and pathways have moved away from the former "math education" and "science education" models into content degrees over the past several years, STEM faculty have taken on more shared ownership for the preparation of future teachers. However, colleges and universities have been slow to change structurally, particularly with respect to the interface between STEM faculty and education faculty, to allow for the depth of collaboration needed. MSPs are often positioned to help campuses build the bridges needed to overcome this silo effect, either through the creation of new multidisciplinary infrastructures or academic programs. One faculty member shared that having chemistry faculty work with colleagues in the School of Education through their MSP has changed what they do in their own classrooms and that they have taken great pride in these changes.

Spanning P-16 boundaries:

MSP projects have provided STEM faculty with the opportunity to span boundaries across the P-16 educational spectrum. In some cases, this has led to increased faculty investment in the STEM pipeline, with participants realizing that they "can't just complain about the students who show up in their class" if they are unwilling to make any type of commitment to K-12 education. A number of MSP projects bring together higher education faculty and K-12 teachers to talk about what they each see and need from their respective positions. Many have also had the opportunity to observe and

provide mutual feedback to each other on the teaching and learning processes in their classrooms, an entirely new experience for some STEM faculty. MSPs have also provided opportunities for STEM faculty to work with peers from other higher education institutions, including community colleges.

Data show that as many as one-fourth of all K-12 teachers initially enter higher education through a community college. One session participant shared that many states (including Maryland and Texas) are formalizing articulation agreements for the first two years of STEM (and other content) majors for secondary teaching, which has not been without controversy (e.g., four-year faculty feeling that student preparation at a community college in mathematics does not equal that of a student at a four-year institution). Again, the MSP model can facilitate broader collaboration around such issues by providing STEM faculty with opportunities to span the boundaries of their department, school, institution, and discipline.

Key Findings: Partnerships cannot assume that individual faculty will find ways of approaching schools, and vice versa. Campuses and schools need to be connected at administrative levels to expedite both access and response. Campus structures and reward systems do not support STEM faculty working with education faculty to change programs. Boundary spanning activities (P-16) are not currently part of faculty roles and responsibilities.

Promising Practices: Dean level involvement is crucial to the success and sustainability of STEM faculty involvement in schools. Institutionalization of administrative structures (multidisciplinary STEM centers or K-12 partnership offices) is a valuable asset in furthering the goals of the MSP program. University administration must build capacity for "boundary spanning" work internally at colleges and universities.

Conceptual Approaches for Analyzing Faculty Engagement and MSP Impact

A series of conference sessions focused specifically on original research that is being conducted by members of the MSP community on topics of faculty engagement, MSP impact, and institutional change. These research studies cut across multiple projects to analyze and assess broader impact. Research of this nature is particularly important since MSP work is innovative and experimental. Cross-cutting studies examine MSP project outcomes at a meta level, analyzing and comparing new approaches to teaching and learning science and mathematics, professional development of teachers and faculty, and partnership activities. Discussions during three such sessions are summarized below as examples:

Measuring Impacts on Institutions of Higher Education – Where are we?

Dr. Joy Frechtling's session addressed the notion that while MSPs are influencing the culture and nature of teaching and learning among participating colleges and universities, there are many unanswered questions about the best way to document, evaluate, and understand such changes. She facilitated an interactive discussion during which

participants shared their ideas about changes that should be examined, evidence that should be collected, and measures or other tools that should be used in carrying out such an evaluation. While keeping in mind the importance of contextual factors that necessarily impact project processes and outcomes – that is, the vast diversity that exists across individual MSPs and institutional participants alike – session attendees developed the following list of preliminary change indicators for colleges and universities:

- New faculty positions created in STEM departments for individuals who have teacher education and/or STEM education experience; and new or joint appointments in education colleges for STEM content experts.

- Changes in institutional materials presented in accreditation reports and other strategic documents (e.g., inclusion of STEM education practices in plans for achieving results).

- New STEM-related initiatives on campus (e.g., STEM centers, additional K-12 partnership projects outside of MSP, additional grants that combine STEM with education, new interactions with research and development offices around STEM education initiatives, institutional fundraising efforts targeted toward supporting STEM education).

- More STEM faculty orienting their research toward STEM education, and this work being valued and accepted (e.g., increased publications in STEM education journals, presentations at national meetings, etc.).

- Changes in the scope of faculty professional activities with K-12 schools that are counted and valued as research and teaching for tenure and promotion beyond the typical, but lower status "service" category.

- Emergence of new campus champions for STEM education at the senior levels of the institution; STEM efforts being marketed by the president, provost, and others in visible leadership positions.

- Increased interactions between STEM and education faculty; adoption of the "community of learners" model that spans individual departments and disciplines.

- Changes in STEM and teacher education curricular and program offerings; increases in interdisciplinary courses.

- Student outcomes: increased number of students deciding to pursue K-12 STEM teaching, decreased attrition among STEM majors.

The Effects of MSP Work on STEM Faculty

Dr. Deborah Pomeroy's session focused on the "push-back" effects of MSP work on STEM faculty related to their teaching, research, and professional careers. Topics for

discussion included what types of effects occur and under what circumstances, factors that facilitate and constrain faculty involvement in such initiatives, and lessons that can be learned about maximizing the benefits of such work. During the session, participants shared both positive and negative push-back effects they had either observed or directly experienced resulting from STEM faculty engagement in school-based outreach.

Dr. Pomeroy has received a supplemental grant to study the role of reward structures for MSP STEM faculty, particularly on the level of individual intrinsic rewards. Her central research question asks, "Can MSP work have positive effects on a faculty member's own research?" Prior to the conference, she had collected several examples of this occurring, and one of the session participants, a STEM faculty member in civil engineering, offered a fifth example. One of her faculty colleagues back at her institution was running a lab in which a student team designed and conducted an experiment that produced an unexpected research result. That faculty member is now in the process of exploring that very result through further research.

Session participants were asked to react to a diagram depicting various components of faculty work (e.g., preparation for classes, instruction, research and writing, professional enrichment) and the relationship among these components and school-based outreach, as in MSP. The ensuing discussion led to a revision of Dr. Pomeroy's existing framework of models for positive push-backs in STEM faculty disciplinary research. The expanded models will be posted on MSPnet for further feedback and refinement and now include:

- *Designing professional development:* When confronting complex concepts they want to help teachers understand, STEM faculty increase their own understanding of their disciplines and research by finding new proofs, examples, and sometimes understandings. When you reorganize knowledge for teaching, you often learn new things.

- *During professional development with novices:* Working in their areas of expertise with novices/teachers in a forum that nurtures questions and sharing of ideas, STEM professors are sometimes prompted by naive questions to rethink their conceptual frameworks. Sometimes these questions take them in directions they have never been before in their thinking about their disciplines.

- *During professional development with content specialists:* Conducting authentic science or mathematical work with teachers and/or other STEM faculty on the outer edges of their disciplinary expertise sometimes raises questions for STEM faculty that cause them to look at their disciplines or their research from new vantage points leading them to new questions or insights.

- *Within MSP itself:* STEM faculty from small institutions find colleagues with whom they can establish virtual departments and networks to enhance their own professional resources, thereby enhancing their research potential.

- *Mentoring novices:* Novices may pursue reconceptualization of a framework within the discipline (through inquiry-based learning), and this may be mentored by the STEM faculty member and hence positively contributes to his/her understanding of the field.

- *Bridging disciplines:* Interdisciplinary discourse among STEM faculty often deepens understanding of their disciplines and builds links to other fields (either within MSP-related work or in future research by STEM faculty in collaboration with others).

- *Grant opportunities:* Improves ability to identify (fundable) education-related research questions and goals that open additional doors to conduct research in the discipline and with others in their disciplines.

- *Designing inquiry activities for students and/or teachers:* Opportunity to think about actual research that students could do, which expands their own thinking about research design.

- Professional enrichment resulting from teams meeting to implement MSP work that improves STEM faculty awareness of better pedagogical practices. (Researchable areas that they are not trained to pursue, especially in education.)

- Sometimes educational outreach helps to focus and articulate goals when writing research.

Transforming Faculty Roles and Reward Systems in MSPs into Sustainable Practice in Higher Education

This session focused on the range of roles and rewards structures that MSPs have created to engage STEM faculty, the resulting impact that MSPs have had on higher education culture to date, and the ways in which NSF can ensure that the best of these changes will be sustained and lead to culture change within higher education. Presenters Nancy Shapiro and Jennifer Frank offered a set of examples of STEM faculty engagement that have surfaced in their study of "Change and Sustainability in Higher Education" (CASHÉ) which demonstrate potential for institutional change. Their examples were drawn from a variety of MSP projects where faculty engaged in different types of STEM course redesigns and professional learning communities. Initially, STEM faculty engagement was highest in the college courses that targeted pre-service and in-service K-12 teachers, but there is evidence of increased interest in redesigning major and general education STEM courses, especially if faculty are also involved in P-16 STEM curriculum alignment issues and teacher education.

Among the most interesting and potentially transformational findings was the data collected on STEM faculty involvement in professional learning communities. Shapiro and Frank suggest that professional learning communities are emerging as a new structure for cultural transformation. While these communities are defined and developed differently at different institutions and in different MSP projects, they can be

defined, generally, as groups of STEM faculty and K-12 science and mathematics teachers who meet regularly to discuss various curricular content issues. These professional learning communities range from discussions of high school assessments, to book discussions, to planning meetings for professional development institutes, to new program development ideas. The key feature, however, is that over time, the faculty and teachers become "bonded" and the communities build the bridges that are necessary for real dialogue and shared agenda setting that leads to change in both K-12 and higher education.

At the same time, Shapiro and Frank facilitated a discussion among the session participants that surfaced a number of challenges and barriers to STEM faculty engagement, many of which have been raised in other sessions. These include the following:

- MSP-type initiatives viewed as community outreach rather than legitimate academic scholarship
- Overextension of responsive faculty members
- Disincentives for tenure-track junior faculty members to participate
- Ambivalence or distrust about proposed changes in institutional rewards systems
- Systemic barriers to changing instructional practices
- Cultural differences between K-12 schools and colleges/universities
- Cultural differences between STEM departments and teacher education departments

Shapiro and Frank shared national data from the MSP-MIS (Management Information System) regarding institutional rewards for higher education faculty to improve their teaching practices or to participate in K-20 teacher preparation or professional development programs. Approximately three-fourths of MSP projects reported some developments among their member higher education institutions in these areas, with the most frequent responses falling into one of the following five categories:

- Workload and monetary incentives
- Promotion, tenure, and recognition policies
- Faculty recognition opportunities
- Professional development opportunities
- Institutional structure/infrastructure enhancements

One of the big questions posed by the MSP program is how much and what kind of "culture change" can be effected by individuals, by institutions of higher education, and by broader policies and practices of the profession. The participants' comments reflect this puzzle:

"Personal effort more than policy changes or reward drive the faculty to participate."

"Engagement springs from their (faculty) role in planning, decision-making, and monitoring a major component of the project."

"It will be a confluence of policy initiatives from the national level, the state level, the system-wide level, and the local IHE level that will contribute to lasting institutional change in faculty engagement in this work."

The CASHÉ project will continue to examine and explore culture change in higher education, and attempt to parse and assess the relative importance of these three forces (individuals, institutions, and broader policies and practices in STEM) for change.

Lessons Learned about the Involvement of STEM Faculty in Deepening Teacher Content Knowledge

Presented by Dr. Iris Weiss of Horizon Research, Dr. Barbara Miller of EDC, and Dr. Dan Heck of Horizon Research, this session focused on the role that STEM faculty play in deepening the content knowledge of K-12 teachers involved in MSP projects. Although the major thrust of the KMD project is to synthesize the MSP learnings with respect to K-12 STEM curricular knowledge and dissemination, all the MSPs have integrated faculty work in their projects, and KMD touched on some of these intersections. This session was built upon the work of a broader NSF Knowledge Management Dissemination research project, also coordinated by the session leaders, that addresses the same topic.

During this conference session, participants discussed the extent to which their MSP projects placed an emphasis on each of five facets of K-12 teacher content knowledge, providing examples of each:

- Knowledge of advanced mathematics and science
- Ways of knowing mathematics and science
- Profound knowledge of basic mathematics and science ideas
- Knowledge of students' mathematical and scientific thinking
- Knowledge of mathematics and science content in the curriculum

Participants also explored the ways in which STEM faculty members play a role in deepening teacher content knowledge in MSPs through such activities as designing and implementing knowledge-deepening experiences, preparing professional development providers to work with teachers, serving as an ongoing content resource for teachers, and assessing the impact of professional development on content knowledge.

As reported by WESTAT, many STEM faculty have become more heavily invested in content delivery for pre-service and in-service teachers through the MSP projects (*Year 3 Report for Effect of STEM Faculty Engagement in MSP – A Longitudinal Perspective*). This KMD project focuses on how their involvement relates to K-12 teaching and learning. KMD is exploring questions such as: What strategies and practices for engaging STEM faculty in deepening teacher content knowledge have proven most effective across projects; how can these findings best be measured, documented, and replicated; and what is the nature of the link between deepened teacher content knowledge and student achievement and learning outcomes?

Key Findings: The meta-analyses demonstrate that that focused, persistent, and positive attention to raising the profile of partnership activities, and direct engagement in teaching and learning science and mathematics, does result in more faculty engagement in MSP-type activities. No clear evidence was presented that this involvement directly improves student learning. Not all MSP projects have made equal progress on changing campus culture to reward and value MSP-type work.

Promising Practices: New faculty appointments, redefining work with schools as part of the tenure and promotion package, and promoting intrinsic rewards all have potential for increasing faculty engagement in MSP-type work.

Cross-Cutting Issues and Themes

Dr. Nancy Shapiro of the University System of Maryland and Dr. Joy Frechtling of WESTAT provided synthesis at the end of the first day of the MSP Learning Network Conference, citing several cross-cutting issues and themes that had emerged. Dr. Shapiro identified two broad sets of issues with respect to STEM faculty engagement. First, promising practices, areas of progress, and potential future avenues for engaging faculty in MSP projects, and second, challenges to maintaining faculty engagement and further encouraging, expanding, and sustaining it.

In terms of promising practices and areas of progress for STEM faculty engagement, Dr. Shapiro observed that a number of MSPs had made substantial use of the learning communities' model (e.g., inter-segmental, cross-segmental, interdisciplinary, STEM faculty and K-12 teachers, STEM faculty and education faculty). For example, when STEM faculty talk to K-12 teachers and realize the external standards and political pressures that they face on a daily basis, these faculty members gain a much clearer understanding of what they need to do to prepare future teachers in their classrooms. Learning communities were cited as a potentially sustainable way for STEM faculty to stay engaged and invested in this work beyond the duration of the MSP grants. In terms

of other areas of progress, the MSP community has also been pushed to broaden its understanding of what it means to provide rewards for engagement in K-12 education and reform. In some instances, this has extended beyond traditional rewards structures for individual faculty members (e.g., stipends, merit pay, recognition) into rewards for departments (e.g., extra faculty lines, joint appointments) and institutions.

In reporting out on remaining challenges that had been shared by conference participants during the plenary sessions and breakouts, Dr. Shapiro noted that MSPs are still predominantly seen as community service rather than legitimate scholarship among STEM faculty and campus leaders. Many of the faculty members who are active participants in MSPs are already overextended, juggling multiple roles, jobs, and identities. In addition, there are significant systemic barriers within institutions of higher education that must still be addressed. Finally, there are cultural differences between K-12 schools and higher education institutions which present challenges for faculty involvement, and while these exist for valid reasons, part of the challenge of MSP work is to figure out how to understand and bridge these differences effectively.

In her remarks, Dr. Frechtling acknowledged that MSP work was exciting and rewarding but not without its challenges and struggles, stating that "forming partnerships between higher education STEM faculty, education faculty, and K-12 teachers is not for the meek." She also reiterated the importance of institutional leadership in this process. She commented that while individual faculty efforts can make a difference in certain times and spaces, the power of having support from the top down had been emphasized over and over again during the conference. Without such leadership support, whether it be the departmental or chancellor/president level, participants realized that it was difficult to bring about any type of continuous change within a college or university.

Dr. Frechtling also raised a question of potential methodological significance regarding what the MSP community actually means by the term faculty "engagement." Is this the same thing as participation? Involvement? Or, is it perhaps something deeper? What does the notion of engagement imply? She compared these questions to the use of the terms "partnership" and "sustainability," which are used with great frequency, although individuals ascribe a wide range of interpretations to them and often struggle with what they actually mean. She probed, "How do we know when we have them, and when we see them, and when they're there and when they're not there?"

Finally, Dr. Frechtling shared conference participant Dr. Ken Gross' (Vermont Mathematics Partnership) analogy of the path of faculty engagement as akin to the evolution of a marriage – if you don't change your marriage over time, it won't be viable. Likewise, the interests and investments of faculty members can and should necessarily change over time as their careers continue to grow and evolve. She observed then, that "one of the challenges is figuring out how to optimize that path. And then how to communicate with the institutions that support faculty, that supporting them appropriately at different ways along that path is not only in the faculty member's interest, but also in the institution's interest."

Conclusion

This year's MSP Learning Network Conference accomplished two key goals: First, it gathered together cutting-edge research and practices that have been carried out over the past four years of the MSP program; and second, it surfaced some of the thorniest challenges to the success of the mathematics and science partnership work – sustaining faculty engagement.

The findings from ongoing project reports and research suggest that faculty involvement in MSP work is critically important to the quality, impact, and outcomes of the projects. Thus far, the collective evidence suggests that this work is worth doing, and worth doing well. That being said, recruiting and sustaining high quality faculty engagement in this work is counter-intuitive for most research faculty, and real culture change will only happen when the higher education community becomes thoroughly convinced that the future of their work is dependent on their sharing responsibility for developing the pipeline for their successors.

The metaphor that comes to mind is "building a bicycle while you are riding it." Only by generating sufficient evidence that faculty involvement is critical to the improvement of K-12 STEM education, will higher education begin to make the substantive changes that will ensure faculty involvement; yet compelling evidence can only be collected when faculty are involved in significant ways for sufficiently extended periods of time.

This conference established a new set of benchmarks for assessing sustainability and impact. By convening the projects around this key feature, NSF has documented important progress within MSP, and helped to establish the next set of goals and outcomes.

Appendix D

Mathematics and Science Partnerships Program
STEM Faculty Summit
December 11-12, 2007

Nancy Shapiro, Jennifer Frank, & Danielle Susskind
University System of Maryland

On December 11-12, 2007, the National Science Foundation (NSF) and the U.S. Department of Education (ED) co-hosted a landmark Summit of science, technology, engineering, and mathematics (STEM) faculty who have been involved in Mathematics and Science Partnership (MSP) projects. The Summit was attended by over 200 STEM faculty representing both NSF and ED MSP projects. After almost five years of grant activity, NSF and ED joined forces to tap into the deep, experiential knowledge of the participating faculty. The Summit was designed to capture and consolidate lessons learned and best practices from these faculty, in particular, and to identify the next steps in advancing this work.

The goals of the Summit were:

- To provide a forum for STEM faculty to share their experiences working with K-12 teachers;

- To identify common themes of efforts that are proving to be successful in working with teachers, models, curricula, and partnerships, which are supported by evidence and are of a scholarly nature;

- To recognize and identify changes that are being brought about both within institutions and among university/college faculty and K-12 teachers in their ways of thinking about science and mathematics, their engagement with substantive content, and their pedagogical approaches; and

- To recognize successes and challenges in working to improve P-20 STEM education and to identify next steps in advancing this important agenda.

The intended outcomes of the Summit were to create a network for STEM faculty engaged in the transformational work of P-20 STEM education through MSPs, and to chart a course for furthering the national effort that advances the engagement of STEM faculty in working to improve the teaching and learning of mathematics, science, and engineering.

In brief, the major findings of the Summit were:

- The partnership model is crucially important for addressing the challenges of improving teaching and learning in mathematics and science, and for constructing a strong, coordinated STEM education system. To transform P-20 education, we need to break down silos and work simultaneously and collaboratively. Successful P-20 partnerships understand how to tap into the strengths of higher education institutions to help support K-12 schools. At the same time, universities and colleges need to recognize their self-interest in P-12 work. Innovative partnerships require higher education faculty to move outside of their individual areas of expertise.

- One of the most underappreciated sources for engaging higher education faculty in MSP work seems to lie deep in the nature of their personal and professional identities – their own curiosity and need to know and learn through experimentation, investigation, and discovery. Multiple pathways for faculty involvement should be identified and encouraged and should not be limited to direct service to teachers or schools. However, faculty involvement must also be linked to institutional rewards and recognition, or even the best intentions will go unrealized. Faculty engaged in the work of K-12 schools are more likely to examine their own pedagogy.

- A unique feature of NSF and ED MSP projects compared to other reform initiatives is the systematic study of MSP experiments using recognized research and evaluation tools to gain new knowledge and understanding. As challenging and problematic as it has been to evaluate partnership projects with so many moving parts, new knowledge has been generated, new models have been tested, and research has generated evidence to support project hypotheses. The research on MSPs leads to new questions for research, building a significant knowledge base.

Consensus on best practices from both ED and NSF projects:

- Supporting STEM faculty in their roles as educational researchers in MSPs, which leads to improved STEM education in colleges as well as K-12 schools;

- Integrating research and scholarship on "how students learn" into STEM classroom teaching K-16;

- Implementing new institutional rewards systems and policies to support MSP faculty;

- Creating sustainable structures for the institutionalization of MSP work; and

- Expanding roles for the disciplinary and professional societies in promoting STEM faculty involvement in K-12 schools and teacher preparation programs.

National Context

The NSF and ED STEM Faculty Summit took place just after the National Science Board published *A National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering, and Mathematics Education System,* and just before the National Mathematics Advisory Panel concluded its year-long study on the best use of scientifically-based research to advance the teaching and learning of mathematics. Both reports respond to the urgent cry for attention to the quality of mathematics and science teaching and learning, which emerged from the 2006 National Academies report *Rising above the Gathering Storm.* MSP projects, both those funded by NSF and ED, have the potential to inform the next generation of federal and state policy recommendations and have funding implications for both higher education and K-12 schools. It was in this national context that this faculty Summit took place in December.

Summit Agenda

The Summit opened with welcoming remarks from Ray Simon, Deputy Secretary, ED, and Kathie L. Olsen, Deputy Director, NSF. First, Dr. Simon described the national context for MSP work, citing how the current crisis in mathematics and science education has largely been shaped by "collective, cultural attitudes toward math and science" and the "level of respect, support, and encouragement for teachers." Stressing the importance of achievement in mathematics and science for all citizens in our global, knowledge-based economy, Dr. Simon emphasized the central role of STEM faculty and other collaborators in MSPs who are engaged in the "business of the future." He stated, "Teaching and learning is the single most important use of our capital – whether it be human, financial, political, moral – than we can ever imagine."

Likewise, Dr. Olsen pointed to the national importance of NSF and ED's MSP work and cited emerging research on student achievement outcomes from NSF's most recent *National Impact Report,* suggesting that strides are being made, but "what we learn needs to be infused across this country." She linked the MSP projects to one of NSF's core investment priorities – the advancement of the nation's achievement in mathematics and science – and characterized the MSPs as "pioneering new ways to bring inspiration, support, and resources to educators and students in order to reach this goal." Dr. Olsen stressed that the purpose and structure of the current Summit was in line with NSF's philosophy of taking a "bottom-up" approach. Namely, that the best ideas about what is working and what is not working in STEM education should come from the educators, researchers, and scientists themselves who are engaged in this work.

In their remarks, Pat O'Connell Johnson, MSP Team Leader, ED, and Daniel Maki, MSP Team Leader, NSF, continued to set the stage for the Summit. They emphasized the fact that through its continued funding and support for MSPs, Congress has acknowledged that STEM faculty and higher education as a whole play an important yet historically underdeveloped role in the improvement of K-12 teaching and learning in mathematics and science. NSF and ED, in turn, have been tasked with examining the impact of these

shifts in thinking and shifts in investments at the federal level. Thus, the purpose of this Summit was to bring together faculty who have been directly involved in this work through MSPs – albeit addressing different discipline-based issues, targeting different teacher and student populations, operating in different local contexts, and functioning on different scales – in order to create an ongoing national discourse about the broader question of what STEM faculty work in K-12 is and can be, as there " … is a lot of interest in how to do this right."

The two-day Summit agenda featured a series of keynote speakers, panel presentations, breakout discussion sessions, and concurrent sessions in which faculty presented on various aspects of their MSP experience. Keynote speakers included Barbara Schaal, Spencer T. Olin Professor of Biology at Washington University and Vice President of the National Academy of Sciences; Linda Slakey, Director, Division of Undergraduate Education, NSF; and Freeman Hrabowski, President, University of Maryland, Baltimore County. In addition, a panel discussion on measuring growth in teacher learning featured Dan Heck, Horizon Research; Sean Smith, Horizon Research; Deb Donovan, Western Washington University; and Kristin Umland, University of New Mexico. Larry Faulkner, President Emeritus of the University of Texas at Austin and Chair of the National Mathematics Panel, served as the closing speaker. In addition, four STEM faculty members provided their own personal reflections on the Summit experience. The full meeting agenda, video archives, and slides for major sessions are posted on MSPnet at http://hub.mspnet.org/index.cfm/msp_Summit_2007.

Summit Report

The purpose of this report is to highlight major themes and findings that emerged during the two-day Summit, with a specific emphasis on breakout sessions during which STEM faculty directly engaged in discussion with each other. This report is not intended to document the Summit in its entirety or to serve as a traditional set of conference "proceedings," but rather to integrate the collective knowledge and insights generated by these STEM faculty members in their individual institutions and partnerships with the broader national context of MSP work over the past five years.

The report begins with a synthesis of themes that emerged from three breakout sessions that were led and facilitated by STEM faculty discussants selected by NSF and ED project officers. These sessions were jointly facilitated by staff members from the Center for Organizational Leadership and Change (CLOC) at the University of Maryland, College Park, who also took notes during each session. Breakout sessions were structured by discipline and included faculty members from both the NSF and ED MSP projects. The first set of breakout sessions focused on why STEM faculty get involved in MSP work; the second focused on their MSP experiences, successes, and opportunities; and the third focused their ideas and vision for charting a course for this work into the future.

The report then summarizes discussion points from concurrent sessions during which Summit participants presented on various aspects of their MSP experience, including faculty rewards structures, models for institutionalizing STEM faculty work in teaching and learning, and the role of professional societies in engaging STEM faculty in K-12, among other topics. It concludes with a synthesis of themes across the two days of the Summit, incorporating additional ideas and concepts from the keynote speakers and other major sessions, and suggesting next steps as NSF, ED, and STEM faculty on college and university campuses across the nation continue to move the MSP agenda forward.

Breakout Discussion #1: Why STEM Faculty Get Involved

The first set of breakout discussions focused on why faculty participants decided to get involved in K-12 work in the first place, particularly MSP projects. Two concurrent groups were convened during this session – one for mathematics faculty and one for science faculty. In each breakout group, four pre-selected faculty members served as panelists and shared their own personal "journey." The four mathematics panelists were Ken Gross (University of Vermont), Hung-Hsi Wu (University of California – Berkeley), Jim Lewis (University of Nebraska – Lincoln), and Joan Ferrini-Mundy (National Science Foundation). The four science panelists were Doris Kimbrough (Chemistry, University of Colorado at Denver Health and Sciences Center), Mike Dalbey (Biology, University of California – Santa Cruz), Robert Culbertson (Physics, Arizona State University), and David Klassen (Physics, Rowan University). Session attendees were then invited to share their own perspectives, responding to the lead question, "What made you, as a STEM faculty member, get involved with teaching teachers?" Faculty wrote down their individual responses to this question and then shared these responses with other participants seated at their table. Designated representatives from each table then recorded and reported out these results to the larger group.

Faculty responses to this question can be sorted into a number of frequently recurring themes:

<u>People/Personal</u>

- Remembering a particularly influential teacher or figure from their own K-12 experience, and having a sense of wanting to give something back;
- Having worked as a K-12 teacher themselves (a number of faculty shared that they had been K-12 teachers prior to attending graduate school);
- Having a persuasive, well-respected faculty colleague who was already active in this work encourage their involvement;
- Wanting to share their "enthusiasm" and "joy" for their discipline with others;

Responsibility

- Having a personal vested interest in the K-12 schools, including school-age children or grandchildren, or friends or family members who were K-12 teachers;

- Feeling a sense of care and concern about current conditions for K-12 students, teachers, and schools, particularly in high poverty areas, and wanting to do what they could to make a difference;

Teaching for Learning

- Watching college-level students struggle in their own courses and departments, and wanting to do something to strengthen their K-12 preparation and the quality of the future pipeline of students entering their institution;

- Having an interest in the science of how people learn;

- Wanting to improve their own teaching and pedagogy;

- Wanting to expand their existing scope of scholarship to include educational research in their discipline;

- Struggling with questions of how to best prepare students in their departments who want to become K-12 teachers;

Professionalism

- Realizing that K-12 teachers should be considered as part of the professional community of mathematicians and scientists, but are often marginalized or excluded; and

- Realizing that working directly with K-12 teachers would have a multiplier effect for leveraging their impact on students, beyond what they could accomplish in their role as individual faculty members.

While a handful of participants pointed to the existence of specific institutional supports that encouraged or facilitated their involvement in K-12 work (e.g., financial incentives and broadening of faculty workload policies to include an outreach component), a far greater number expressed concerns about challenges, barriers, and disincentives for STEM faculty who wanted to do this work, particularly in the promotion and tenure process. Some faculty shared that they had come to K-12 work only after successfully earning tenure in their STEM department, at which time they felt that they were more secure in their standing at the institution and had the latitude to explore new territory professionally. For others, the path to involvement was far less intentional. Many faculty shared that their role in K-12 had evolved quite accidentally or serendipitously, with opportunities coming to them after giving a talk or presentation, serving on a

committee, volunteering their time in a related capacity, or making a particular contact with another faculty member or teacher.

One participant during the mathematics breakout session observed that every single faculty member at the discussion table had been substantively involved in some type of K-12 outreach prior to joining an MSP. The critical question, then, becomes one of bringing greater numbers of STEM faculty who are new to this work into the MSP community, including faculty who are at different stages in their careers. While faculty felt that their individual efforts were important and made a difference, they did not necessarily view MSP projects as a sustainable model for bringing about wide-scale change if they were only able to reach a limited number of higher education faculty who were already favorably predisposed to this work.

Breakout Discussion #2: MSP Experiences, Successes, and Opportunities

The second round of breakout discussions was also structured by discipline (three groups for science faculty and four groups for mathematics faculty) and led by pre-selected faculty teams from the NSF and ED MSP projects. The purpose of these sessions was to examine faculty experiences, approaches, successes, challenges, and opportunities as related to their MSP involvement. The following guide questions were offered to help structure each discussion:

- What do you view as the most important experience you have had as a STEM faculty member in this MSP, and why does this stand out for you?

- Considering the aspect(s) of your MSP in which you are involved (you as an individual STEM faculty member), how did you decide to take the approach(es) you did?

- What do you view as the greatest successes you have had working in the MSP and what went into making them successful, vis-à-vis planning, implementation, evaluation, etc.? What convinces you that you have had these successes?

- What opportunities and/or challenges do you believe remain in terms of the role of STEM faculty in improving P-20 STEM education, particularly in regards to pre-service and in-service teachers?

Science Faculty Discussions

Three categories of responses emerged from the science faculty discussions: experiences and successes with fellow faculty members, with K-12 teachers, and with students. These faculty members also discussed the personal benefits they had gleaned from their involvement in MSP partnerships, their observations specific to science content, and the critical challenges that they faced during the course of their projects. Finally, they shared

general perspectives on such topics as testing, evaluation, teacher anxiety, technology, and the role of colleges and universities.

Faculty Experiences

Several of the science faculty discussants acknowledged the importance of preparing themselves and their fellow faculty colleagues for MSP work through professional development in inquiry-based approaches to teaching science. Many had worked directly with mathematics and science specialists within their partner school districts, or mathematics and science coordinators or coaches within their partner schools. Participants noted that through their work, they and their colleagues realized that K-12 teachers were "intellectual beings (*sic*)," which speaks volumes about the cultural gap between public school teachers and college/university faculty. For example, several STEM faculty members noted that during their MSP partnerships, participating teachers had become members of STEM professional societies, presented at conferences, and co-authored papers for publication, garnering professional recognition and enhancing their investment in the partnership.

As the conversation turned to focus on how faculty could assist K-12 teachers, one science faculty member remarked that they "needed to engage teachers in projects rather than formulas." Some praised the work of interdisciplinary, integrated courses for teachers in which biologists, chemists, and physicists were all talking together and learning each other's language and terminology. Faculty also shared success stories about working with teachers on inquiry instruction, structuring lesson plans with teachers that require students to collect primary data firsthand, bringing teachers and students to university labs and other scientific settings, helping teachers create time for self-assessment and reflection, and emphasizing fundamental concepts from science that cut across the disciplines. This active integration of pedagogy (inquiry instruction) and content (laboratory work) is an essential feature of the MSP partnerships.

Personal and Professional Benefits

Science faculty also discussed personal and professional benefits resulting from their MSP participation, including substantial expansion of their knowledge, experience, and understanding of the K-12 context. Several participants commented that they had come to appreciate the complexity and myriad of pressures that K-12 teachers face on a daily basis. The MSP partnership activity illuminated the teaching and learning environment specific to the K-12 science community. The faculty were impressed with how eager many of the teachers were to learn and how some with less content mastery who seemed to hold back during the professional development institutes and other MSP activities turned out to be top notch teachers in their classrooms.

Another important set of faculty observations involved the role of cultural differences in teaching and learning. It became clear to STEM faculty that they did not have formal training in differentiated student learning styles or cultural contexts. New realizations about how different people view the natural world were eye-opening experiences for

some faculty members. A number of the participating faculty "confessed" that their MSP experience helped them rediscover how much they really liked teaching, and stimulated them to incorporate new approaches to improve their own courses and instruction at the college level.

Science Content

Focusing on what STEM faculty learned about K-12 science content revealed some disturbing gaps in knowledge that have significant consequences for STEM teaching and learning. STEM faculty noted that many of the science teachers they had worked with did not have the basic mathematics skills necessary to teach science successfully. They emphasized that teachers needed to develop a better understanding of scientific processes and methods – the "nature" of science, the "doing" of science, and the "why" behind things – not just scientific facts. Faculty also noted specific challenges to integrating the pre-engineering curriculum into K-12 schools.

In terms of strategies, the discussants noted that science faculty and teachers alike needed to come together at all levels to teach each other about their respective disciplines in order to probe the overarching science concepts that connect them. They observed that science teachers, particularly in the K-8 grades, need to know and understand the basic unifying principles that cut across the sciences. They also need to have the confidence, skills, and resources to illustrate scientific principles through experimentation and inquiry-based instruction with students in the classroom. At the same time, college level faculty need to remember and remain sensitive to the reality on the ground: that public school teachers generally do not have the same level of access to scientific supplies and equipment as faculty, which presents a serious set of very real constraints on the curriculum.

Critical Challenges

The science faculty continued their discussions with a conversation about the challenges they themselves and their MSP partnerships had faced. These challenges tended to fall into one of two broad-based categories: challenges to "thinking P-20 science" and challenges with other faculty in their home institutions. First, faculty discussed the "disconnects" and lack of integration they saw throughout the science education pipeline: from elementary, middle, and high school, to community colleges, four-year institutions, and graduate programs. They pointed to the challenges associated with being spread across several sub-disciplines within the sciences versus belonging to the "Mathematics Department" or "History Department," often making it difficult to coordinate science outreach or reform efforts with K-12 schools in any meaningful way. Because "the sciences" are not centralized, it is more difficult to set a coherent, aligned agenda or provide leadership for P-20 science initiatives. Sciences are dispersed across several science departments (at the institutional level) or several professional societies (at the disciplinary level), and it is too easy for college science departments to relinquish responsibility for "teaching science."

Secondly, several faculty members shared their struggles with getting their non-MSP faculty colleagues to reflect on their own responsibility for the higher education portion of the STEM pipeline, instead preferring to blame K-12 teachers and schools for their students being under-prepared to succeed in college-level science courses. They also recognized the need for higher education faculty to consider different ways of teaching and assessing student learning and understanding in the sciences in order to reach students with differing learning styles.

Other Perspectives

As the science faculty continued to reflect on their experiences, a few additional topics emerged through their discussions. Evaluation was generally seen as a critically important aspect of the MSP projects leading to productive, goal-directed, evidence-based work. The faculty participants stressed the importance of setting clearly articulated goals and measuring outcomes with evidence. However, they strongly suggested that schools use alternative approaches to testing and assessment in science that ask students to consider such questions as, "What big ideas does this problem build on, and what kind of big ideas might a solution to this problem lead to?"

The faculty also recognized that some K-12 teachers experienced anxiety when working with college scientists and faculty because they were being pulled far outside their areas of expertise. In the most successful projects, faculty pointed to strategies for overcoming these tensions, such as professional learning communities and reflective journaling activities. Science and mathematics faculty are used to the "messiness" of their disciplines, and are used to not knowing answers. They realized that teachers need to be coached and guided to become more comfortable with "on their feet" problem-solving skills in front of the classroom while students are observing and participating. The faculty also observed that teachers are not always comfortable with using technology in instruction and in their own professional development, and many could use more support in this area.

Finally, the discussion came around full circle, when participating faculty suggested that colleges and universities with MSP projects needed to look internally and apply these same principles in their own practice, particularly in thinking about the redesign of entry-level and general education STEM courses that reach large numbers of first-year students transitioning from K-12 to college.

Mathematics Faculty Discussions

In a separate, but parallel set of breakout sessions, mathematics faculty examined the same guiding questions. The major themes that emerged from their discussions addressed topics similar to those that the scientists surfaced: significant MSP experiences, mathematics content, ongoing challenges, and partnership sustainability. Because there was substantial overlap on many of these themes with the science faculty discussions, this section focuses on the new ideas that emerged from the mathematics faculty.

Experiences: Personal and Professional

The experiences that the mathematicians shared ranged from personal to professional. Some of the faculty described being "inspired," energized, and impressed by the creativity and the hard work of the teachers who face difficult resource constraints and content limitations. Others acknowledged that being part of the MSP had changed the way they teach. More faculty from MSPs found themselves participating in professional development related to their own pedagogy and coming to appreciate new opportunities to work with the education faculty on their own campuses. The mathematics faculty's own level of sophistication in pedagogy and praxis increased through their participation, and some indicated that the impact on their own campuses extended to curriculum redesign as a result of interaction with K-12 teachers. In addition, the discussants acknowledged that they are able to better understand the complexity of the K-12 education system through these projects, which helps them to understand the big picture.

They also noted that they gained an increased understanding of the complexities involving second language learners, which had positive consequences for their own instruction. They found that even the most practical collaborations with teachers were situated in "big ideas" and on the high standards that are necessary for expanding the STEM pipeline.

Mathematics faculty shared what they considered best practices – what seemed to work best for teachers. One participant noted that her model entails the STEM faculty member modeling teaching first, while teachers observe. Then faculty and teachers team teach together, and then teachers teach alone. Another discussant offered a different model. In this partnership, the teachers and students participated and learned together. Then, teachers took the learnings back to their own classrooms after seeing that it works with students. Still, another faculty member suggested the teacher-leader model as a way to reach more teachers. Summer institutes with collaborative teaching teams (e.g., mathematicians to answer content questions and a forestry expert to answer application questions) introduced exciting new possibilities through MSPs. It became clear throughout this discussion that the particular strategy was not the issue; rather, continued engagement and dialogue between faculty and teachers were the critical factors. In particular: dialogue to talk *with* teachers (not *at* them).

Mathematics Content

A clear theme in the mathematics conversations related to the persistent and discouraging reality of the serious content needs of elementary and middle school teachers. The mathematics faculty felt that these deficiencies need to be assessed, and addressed at both the pre-service and in-service levels. They emphasized that teachers need to understand the connections and big picture of mathematics concepts. For example, they noted that teachers need to understand that arithmetic thinking leads to algebraic thinking; that a topic like "recursion" is not just an elementary concept, but is a key aspect in understanding other critical areas of mathematics. For this reason, the participants stressed that teachers need to learn from faculty who have deep knowledge and who can

make both vertical and horizontal connections across the mathematics curriculum. The faculty described the process of moving from the concrete to the abstract as "mathematizing." At the same time, they also acknowledged that they need to understand early mathematics learning better in order to effectively teach these fundamental concepts to current and future teachers.

Ongoing Challenges

The mathematics faculty recognized a need for a mindset or paradigm shift in terms of gaining greater respect and appreciation at all levels and across all parties. This paradigm shift begins with respecting teaching as a profession. It includes university faculty respecting K-12 teachers (and vice versa); and STEM faculty respecting education faculty (and vice versa). It requires that STEM faculty avoid an attitude of "arrogance and disdain" for education. In addition, the participants challenged the highest levels of college and university leadership to value faculty contributions toward improving P-20 education.

The mathematics faculty considered the challenges of MSPs in terms of collaboration and partnerships. First, there is a greater need for communication and collaboration across departments. Specifically, the faculty felt that the Department/College of Education and Department/College of Mathematics need to participate in more interdisciplinary work. Second, the faculty recognized the importance of listening to experts in the K-12 system (teachers, administrators, curriculum specialists) and acting in congruence with these experts. Continuous collaboration between faculty and teachers is critical.

A troubling aspect of the MSP work is the shared sense of a lack of control over K-12 systemic change (school reform). As illustrated by one faculty member during the session, the "bouquet approach" does not work. Systemic change depends on a critical mass of participating STEM faculty. They expressed frustration at the "lack of sophistication in our understanding of how to make systemic change in mathematics education." They also noted that the extended "time horizon" contributed to their sense of frustration – changing schools and universities takes too long. Importantly, the faculty also suggested that they need to be involved in the setting of state standards. They agreed that unless they participate in this work, they are abdicating their responsibility. Fortunately, they saw the MSPs as one strategy for overcoming these barriers, and in some ways, as a means to "defy the K-12 system and make teachers feel connected and less isolated."

Their conversation turned toward persistent issues of educating future teachers. They recommended that universities that do not have dedicated Departments/Colleges of Education consider how they will address pedagogy issues, since many of their mathematics majors do in fact go into teaching. If these pre-service teachers are not receiving appropriate preparation for the classroom, then we are seriously negligent of our responsibilities. The faculty also noted that it is imperative to ensure that mathematics faculty have the opportunity to approve graduate-level mathematics courses for teachers. Finally, the discussants noted that it is important to remove barriers for

teachers who want to pursue graduate education, but have not yet met the calculus requirement.

Finally, the mathematics participants considered the cultural differences between faculty and the teachers they work with. They noted that many teachers, students, and others come to the study of mathematics with a great deal of "negative baggage." These populations may have spent eighteen plus years hating mathematics or may feel anxious and incompetent. The faculty acknowledged that they, and the programs they are part of, need to address this psychological state in order to help learners build their self-confidence and develop a more positive view of mathematics.

Partnership Sustainability

Like the scientists, the mathematicians were concerned about how to sustain this work when the formal partnerships end. They noted that teacher leaders are emerging through mentoring and professional development programs, and are one important key to sustainability. Along these same lines, it helps to recruit veteran teachers who have credibility with other teachers. They recognized the value of the teams and networks of teachers that have been developed over the course of the MSP projects, including the important work of developing their own instructional materials, which helps keep the work in the schools.

Still, the mathematics faculty recognized that critical support structures are a function of leadership, at both the K-12 schools and in colleges and universities. Unless there is a critical mass of STEM faculty involved in the work, the efforts will wither and die over time. Equally important are challenges related to rewards and supports. The mathematics faculty felt that it is necessary for STEM faculty to receive clear and consistent recognition and support from university administrators in order to continue to do this work. They noted it is critically important for junior faculty to be rewarded for this work, but that all faculty who engage with K-12 schools need to be supported through release time, merit increases, and consideration in the promotion and tenure process.

Breakout Discussion #3: Charting a Course for the Future

In the third set of breakout discussions, Summit participants were challenged to think strategically about ways to continue to advance the agenda of STEM disciplinary faculty playing a vital role in improving STEM education, particularly in K-12 schools. The discussions were organized around three focal questions:

- What do you see as the most important next step for STEM disciplinary faculty in working to improve K-12 education?

- What should happen within your own department, within your own college or university, within your own state, within the schools, within your professional societies, and at the national and federal levels?

- What is needed, both short-term and long-term, in order for these efforts to be successful?

The major themes that emerged from the three science faculty breakout sessions and three mathematics breakout sessions are captured below.

First, faculty revisited ongoing discussions about providing ***institutional incentives and rewards*** for getting STEM faculty involved in this work, particularly the validation of faculty scholarship focused on education research. They recommended that the STEM disciplinary societies become involved in developing standards and measures for evaluating the intellectual merit of MSP-type work. Faculty also expressed the need for identifying ***various avenues of involvement*** for faculty both inside and outside the classroom to match their talents, interests, and time commitments. As noted frequently during the Summit, involvement in K-12 schools should not be a "one-size fits all" enterprise for STEM faculty. At the same time, several participants stressed that it was important not to underestimate the impact of having highly-respected "big name" professors associated with these projects whenever possible, as these individuals can use their influence to get other faculty to participate and administrators to stand up and take notice.

Participants also urged NSF and ED to think strategically about ways to ***engage academic and administrative leaders*** in dialogue around the importance of involvement in K-12, potentially through their own conference or summit focused on institutional leadership issues in supporting and sustaining this work. Faculty recognized that levels of administrative buy-in and support varied substantially across their individual campuses, and many regretted that they would not have a "support system" for moving the ball forward once they returned from the Summit.

Faculty were particularly adamant that more college and university faculty need to be involved in ***informing the development of K-12 state standards for mathematics and science.*** Mathematics faculty in particular recognize that the alignment of mathematics related skills and competencies is a significant barrier to increasing the STEM pipeline. Rather than blaming K-12 schools and teachers for the under-prepared students who enter their college and university classrooms, faculty must play a role in developing a more rigorous, integrated STEM curriculum across the primary, middle, secondary grades that prepares students for college-level work. STEM faculty should also become involved in the creation of assessment tools, beginning with placement tests, but "back-mapping" to the assessments that would anticipate those college placement tests.

The mathematics faculty took special note of the importance of reading and English comprehension skills that often prevent students from being able to understand the mathematics and science in the first place. They recognized that these troubling issues are particularly endemic in low income, rural, and urban settings in which large numbers of students are performing well below grade level in reading. Additionally, faculty suggested that more research should be focused on helping the highest-performing K-12

students succeed and excel in mathematics and science, given that current state standards and approaches to testing and assessment seem aimed primarily on bringing the lowest-performing students to the most minimal standards.

Faculty felt that they should ***play a stronger role in pre-service preparation programs on their campuses, particularly for elementary and middle school teachers.*** Traditionally, STEM departments have had much less involvement in early-learning and elementary programs compared to discipline-specific secondary teacher certification. Faculty suggested engaging elementary and middle school teacher candidates in real-world STEM-oriented problems and issues while they are still in college. They recommended exposing these pre-service teachers to university and industry labs where science is taking place, getting them more comfortable and confident with the specific content they will teach, and supporting them in the use of technology for mathematics and science instruction.

Faculty stressed that future elementary and middle school teachers need to know and understand the basic unifying principles that cut across the sciences, as well as have the ability to understand and apply the fundamentals of mathematics. Teachers need to be able to convey this understanding to their students through age-appropriate forms of experimentation and real-world examples in their teaching. Faculty want to foster the capacity for teachers to be comfortable "not knowing answers" in front of students and being able to engage them in problem-solving by example. They acknowledged that these reforms begin with modeling effective instruction in college and university STEM courses, incorporating research-based instructional methods such as inquiry rather than relying on the more traditional lecture and recitation model.

Likewise, faculty participants felt that they could play a stronger role collectively in ***advocating for K-12 teachers and promoting their visibility and recognition***, often beginning with changes in their own attitudes toward the teaching profession. Why, they asked themselves, do faculty members sometimes hesitate when a strong student in mathematics or science expresses an interest in becoming a K-12 teacher? Why do teachers often view professional development as a form of "punishment," as a means for pointing out some type of personal deficiency in their knowledge or background? And are faculty so sure that all teachers have equally fond memories of their experiences in STEM college classrooms? Participants emphasized the importance of STEM faculty and teachers building necessary levels of trust in order to work together. They may share an interest, or even a love of their discipline, but they inhabit two separate worlds, and need to build bridges of understanding. Faculty who are not sensitive to these factors in their approach to K-12 work can perpetuate these problems rather than help address them.

Finally, faculty were concerned that MSP efforts be regarded as more than just the "latest fad" by their institutions, faculty colleagues, and K-12 partners. Many of the Summit participants had decades of prior work in these areas and had watched institutional interests and federal funding priorities with respect to involvement in K-12 wax and wane over time. They had seen various approaches tried, then tossed aside, then brought back off the shelves to try once again. The faculty felt that the creation of ***visible, accessible,***

and centralized repositories for capturing MSP findings and knowledge was particularly important for sustaining momentum and ensuring that MSP movement was not just another example of higher education and K-12 "reinventing the wheel" around education reform and partnership work. In general, participants felt that individual commitment could only take these efforts so far. To have lasting effects, higher education institutions need to assume more responsibility for sustainability beyond the MSP grant funding.

Perspectives on Scholarship and Institutional Changes

Five concurrent breakout sessions were held during the Summit that focused on various aspects of scholarship and institutional changes related to MSP work:

Research as a Strategy for Developing Cooperative Efforts among Educators and Scientists
- Pamela Mills, Hunter College
- Madeleine Long, Hunter College

Changing the IHE Reward Structure to Support the Scholarship of Teaching and Learning: PRISM and the New University System of Georgia's Advocacy Policy
- Sabrina Hessinger, Armstrong Atlantic State University
- Fredrick Rich, Georgia Southern University

Model for Institutionalizing Support for STEM Faculty Work in Teaching and Learning: A STEM Center and a Regional Compact
- Kimberly Childs, Stephen F. Austin State University
- Victor Donnay, Bryn Mawr College

Incorporating the Science of Learning in STEM Teaching and Learning: How People Learn, Taking Science to School, and Ready, Set, Science!
- Heidi Schweingruber, National Research Council, National Academy of Sciences
- Andrew Shouse, National Research Council, National Academy of Sciences
- Tom Keller, National Research Council, National Academy of Sciences

The Role of Professional Societies in Engaging STEM Faculty in K-12 Work
- Sam Rankin, American Mathematical Society
- Michael Pearson, Mathematical Association of America
- Warren Hein, American Association of Physics Teachers
- Kenna Shaw, American Society of Human Genetics

Each of these presentations addressed multiple topics, many of which echo the observations and findings of the earlier sessions. Several issues of significance are worth noting from these sessions as they relate to our emerging understanding of the role of STEM faculty in MSPs. Specifically, these sessions probed topics including the following: the role of STEM faculty as education researchers, the implementation of new

faculty rewards policies and systems in higher education, the creation of sustainable structures for the institutionalization of MSP work, the real challenges related to the integration of learning theory and research into STEM classroom teaching, and emerging roles for STEM professional societies in promoting faculty involvement in K-12 schools and teacher preparation programs.

The first breakout session led by Dr. Mills and Dr. Long focused on the ***involvement of STEM faculty in education research*** through the creation of a "responsive research network" in the MSPinNYC project. The purpose of this network is to produce timely research responses to address pressing education issues and concerns in the partnership; to specifically use research as a strategy for involving STEM faculty in MSP work; and to create a collaborative, resource-rich environment for faculty participants. Breakout session attendees discussed challenges related to STEM faculty engagement in education research, including differences in research methodologies and theoretical orientations, as well as the constraints of social science research in general (e.g., generalizability, dealing with complex cases and systems in which it is difficult to isolate variables and engage in experimentation). To help address these challenges, MSPinNYC's research network builds bridges between STEM faculty and education researchers in collaboratively framing and studying the most important questions in their MSP work – thereby complementing each other's strengths and approaches and informing each other's research and scholarship.

The second presentation, by Dr. Hessigner and Dr. Rich of the Partnership for Reform in Science and Mathematics (PRISM) in Georgia, addressed another major theme of the Summit – ***faculty rewards.*** PRISM's experience provides an interesting study of how a formal policy change can help advocate for involvement in K-12 schools and teacher preparation in ways that are mutually satisfying and beneficial for both faculty and their institutions. Addressing the rewards structure was a goal outlined in PRISM's original MSP proposal to NSF, also commonly referred to as "Strategy 10" (since it was the tenth goal of the partnership). These efforts culminated in a "Faculty Work in the Schools" advocacy policy from the University System of Georgia Board of Regents, which states that "University System institutions that prepare teachers will support and reward all faculty who participate significantly in approved teacher preparation efforts and in school improvement through decisions in promotion and tenure, pre-tenure and post-tenure review, annual review and merit pay, workload, recognition, allocation of resources, and other rewards."

During their breakout session at the Summit, Dr. Hessinger and Dr. Rich stressed that policy implementation had to occur all the way up to the chancellor's office, as college and university presidents are asked to demonstrate how they are advocating for this policy in their annual review. Now, faculty scholarship published in education journals is valued, and the activity of teaching teachers is no longer relegated only to the category of "faculty service." At the same time, however, they acknowledged that there are ongoing challenges on campuses with faculty who have little understanding of or regard for the scholarship of teaching and learning, work with K-12 schools, or teacher preparation programs.

The third concurrent session focused on the topic of ***institutionalization and sustainability of MSP efforts***. Dr. Childs from the Texas Middle and Secondary Math MSP and Dr. Donnay from the MSP of Greater Philadelphia presented two different models to illustrate how their individual projects are tackling these issues. For example, Stephen F. Austin State University has created a new STEM Center for Teaching and Learning to serve as a focal point for engaging faculty from across the campus in STEM outreach, education, and research. Likewise, Dr. Donnay from Bryn Mawr College shared his experiences with the creation of a formalized regional compact among participating higher education institutions and other organizations in the Philadelphia area as an outgrowth of their MSP work, culminating in the creation of the "Greater Philadelphia Regional Compact for STEM Education." The vision of this compact is to increase the region's capacity for building a more robust STEM education and workforce infrastructure. During the discussion, session participants shared various additional strategies for institutionalization on their own campuses, including the following:

- Generating a "critical mass" of faculty participants on campus;
- Avoiding the tendency to rely solely on external funding or indirects to support this work, but garnering institutional resources such as campus office space and staffing;
- Leveraging resources with outside funders, including corporations and foundations;
- Finding the "currency of the realm" at the institution – student recruitment, enrollments, new academic programs;
- Educating campus leaders about MSP findings and impact;
- Getting school district buy-in and endorsement that this work is important and needs to continue; and
- Bringing changes to scale by partnering with other institutions and organizations.

The fourth breakout session with Dr. Schweingruber, Dr. Shouse, and Dr. Keller of the National Research Council (NRC) addressed a theme that was discussed at several points throughout the Summit: ***the integration of research and theory on how people learn and the application of this knowledge in STEM teaching and pedagogy***. The presenters distributed and discussed the recent NRC publication *Taking Science to School: Ready, Set, Science!* Using numerous case studies and examples, this book is intended as a guide for teachers to help them take the latest research on teaching and learning and put it into practice in K-8 science classrooms. More specifically, it applies findings from NRC's 2006 report *Taking Science to School: Learning and Teaching Science in Grades K-8*. Among other findings, this report presents four strands of science "proficiency" as learning goals for students and as a broad framework for curriculum design, that students must (1) know, use, and interpret scientific explanations of the natural world; (2) generate and evaluate scientific evidence and explanations; (3) understand the nature and

development of scientific knowledge; and (4) participate productively in scientific practices and discourse.

This NRC presentation sparked a lively discussion among session participants about the challenges of integrating research on teaching and learning into policy and curriculum, particularly in the K-12 sector. Namely, that the findings of the research on teaching and learning science are in direct conflict with the current priority of teaching toward standardized tests. The work raises serious concerns about the lack of time given to the actual processes of science in the classroom. Thus, while we now know a great deal about how students learn science, we find systemic barriers in place that prevent this knowledge from reaching and benefiting K-12 teachers and students.

The final breakout session, jointly facilitated by Dr. Hein, Dr. Pearson, Dr. Rankin, and Dr. Shaw, highlighted ***the role of the professional societies in encouraging and rewarding STEM faculty engagement in teacher preparation and K-12 schools.*** Professional societies have been cited as an important constituency in MSP work through their role in establishing norms and culture for faculty within the individual STEM disciplines, as well as in defining and valuing "what counts" as legitimate research and scholarship. The presenters shared relevant student and teacher statistics in each of their fields, as well as discussed various challenges and strategies for strengthening and increasing this pipeline from their perspective, including undergraduate education reform. They also discussed the role of specific groups within their membership that have been charged with studying these issues and developing strategies to address them, including the Committee on Education of the American Mathematical Society, Committee on the Mathematical Education of Teachers of the Mathematical Association of America, and the Committee on Teacher Preparation of the American Association of Physics Teachers. In light of these developments at the national level, however, there is evidence that substantial challenges still remain for faculty on individual campuses. In a recent national survey of deans and department chairs conducted by the American Society of Human Genetics, 62% of respondents indicated that they did not encourage faculty work in K-12 education. In terms of faculty evaluation criteria for tenure and promotion, publications and funding ranked at the top, with student opinions of instruction ranking near the bottom in value.

Discussion of Implications for STEM Teaching and Learning P-20 from Invited Presenters

Keynote Speech: *Global Issues and the Scientific Enterprise: Transforming High School Science Teaching and Learning*
Barbara Schaal, Spencer T. Olin Professor of Biology, Washington University, and Vice President, National Academy of Sciences

During her keynote speech, Barbara Schaal shared her experiences with Washington University's MSP, Life Sciences Teacher Institute: Education for a Global Community, the goals of which are to develop master teachers of high school biology, to increase the interest and achievement of high school students in the sciences, and to build the capacity

of teacher participants as educational leaders. This MSP institute focuses on enhancing teacher content through compelling examples, research projects, and rich web-based learning opportunities. It culminates in a master of science in biology earned over two summers in residence, with online learning during the school year. The focus on global issues was selected to help teachers use biology content to educate students about global issues that affect their everyday lives – reaching both students who may go on to pursue the sciences, and those who may not. An increased understanding of the impact of globalization not only results in a more educated citizenry well-equipped to make informed decisions, but also helps students develop an empathy for and understanding of diverse cultures.

Particularly pertinent to other themes during the Summit were Dr. Schaal's observations about why this MSP has worked at Washington University, which, among other factors, she cited as having an outstanding outreach program, high faculty interest, excellent teacher participants, and administrative support from the department chair and dean. She also underscored the importance of building a culture on campus that has fostered support for MSP work. For example, she shared that the department chair held a meeting when the MSP RFP originally came out, stressing the importance of faculty going after this grant. She also shared that faculty publications resulting from the MSP count as scholarship and junior faculty members are paid and supported for their involvement.

Keynote Speech: ***Implications for All Students of STEM Faculty Involved in Pre-service Education of Teachers***
Linda Slakey, Director, Division of Undergraduate Education, National Science Foundation

Linda Slakey's keynote speech addressed a common theme during the Summit – the impact that MSP participation has had on individual STEM faculty members, and the catalytic effect it has had on transforming their own ideas and practices in teaching and learning. She traced the origin of STEM faculty involvement in related NSF initiatives, including the Middle School Mathematics Initiative in the 1980s and the Collaborative for Excellence in Teacher Preparation (CTEP) in the 1990s. MSPs have continued in this same tradition with STEM faculty leadership and participation as the cornerstone of these reform efforts.

Drawing on her own experience as a STEM faculty member, Dr. Slakey shared her personal transformation from the role of teacher-as-presenter to the role of serving as a catalyst for facilitating student learning. She described student-centered learning as starting where the students are, using problem-solving from the beginning, mixing both individual and collaborative learning, and providing real-time two-way feedback via a classroom communication system (particularly taking advantage of instructional technology). She cited research supporting that interactive methods of teaching are more effective in helping students develop conceptual understanding (including the research of Indiana University physicist Richard Hake), while also pointing to the difficulties of individual STEM disciplines reaching consensus about the appropriate diagnostic assessment tools to measure underlying theories and concepts.

In the discussion that followed Dr. Slakey's keynote address, individual tables of Summit participants were asked to address the following topics: impact of STEM faculty on their MSP, impact of their MSP on STEM faculty, and supporting factors that have catalyzed such changes.

Examples of Faculty Impact on MSP

- Providing challenging material to teachers and students, including open-ended problems
- Giving teachers the confidence and space to be able to say "I don't know," thereby paving the way for inquiry-based teaching and learning
- Showing teachers that higher education faculty are approachable and willing to collaborate
- Providing teachers with support, evidence, and clout when they receive "pushback" from school administrators (and even parents) about making pedagogical changes

Examples of MSP Impact on Faculty

- Using more interactive, student-oriented approaches to teaching; less reliance on lecture
- Being more transparent in their teaching; inviting feedback and peer-to-peer observation
- Fostering a climate where faculty now initiate discussions about teaching with other faculty, and understand terms such as "learning outcomes" and "rubrics"
- Developing a greater awareness of the needs of pre-service teachers in their STEM classrooms
- Providing an avenue for continued growth and change for faculty who were already involved in such initiatives prior to MSP

Factors Catalyzing Change

- Need to have campus administrators at all levels (department chair, dean, provost, president) who buy into the importance of faculty development and MSP work
- Need to have faculty who are committed to this work and who believe that their efforts and these resulting changes can make a difference

Panel Presentation: ***Measuring Growth in Teacher Learning: How Do You Know Whether They Are Learning What You Want Them to Learn?***
Dan Heck, Horizon Research, Inc., Sean Smith, Horizon Research, Inc., Deb Donovan, Western Washington University, Kristin Umland, University of New Mexico

This panel presentation focused on one of the recurring themes of the conference: the measurement of outcomes related to MSPs. First, Dan Heck and Sean Smith of Horizon Research, Inc., shared several tools for assessing impacts on teacher knowledge for mathematics and science teaching, including their own work at Horizon, as well as the work of others in the field, both within and outside of the MSP community. Based on their research, they presented "domains" of teacher knowledge as disciplinary content knowledge, representation of ideas, student thinking about content, diagnostic strategies for student thinking, sequencing ideas for students, and strategies that move student thinking forward. Among the examples and tools they presented for assessing teacher knowledge were Learning Mathematics for Teaching (LMT), Knowledge of Algebra for Teaching, Diagnostic Teacher Assessments in Mathematics and Science, Assessing Teacher Learning about Science Teaching (ATLAST), and Misconception Oriented Standards-Based Assessment Resource for Teachers (MOSART).

Deb Donovan of Western Washington University discussed the use of ATLAST in her MSP (North Cascades and Olympic Science Partnership) to measure the extent to which their courses had increased content knowledge for teachers, in addition to using surveys, focus groups, interviews, and documentation reviews. When used as life science and earth science content assessments, Dr. Donovan and her colleagues found significant teacher gains from the pre- to post-test, as well as from the pre-test to one year out. Since sub-items on the inventory are keyed to common science misconceptions and distracters, faculty have been able to gain more detailed feedback about what teachers know, or what they think they know, and a better understanding of the underlying assumptions upon which they are basing their correct or incorrect selection of answers.

Kristin Umland of the University of New Mexico described her project's experience with using the LMT, and the fact that it had helped expand her own thinking about how to construct test questions and use assessments in her work with teachers. For example, she indicated that she was now more likely to create problem sets situated in actual classrooms with students and teachers as protagonists. In addition, she was more likely to ask questions that expose and address underlying student and teacher misunderstandings and misconceptions about mathematics. At the same time, Dr. Umland discussed the real challenges related to the implementation of assessment programs of this scale and nature in the MSPs, which can be problematic without engaging in long-term assessment planning at the onset of the project, providing sufficient funding for research and evaluation, and building long-term relationships with teachers who remain in programs long enough to complete the entire assessment cycle.

Leadership Perspectives on Faculty Involvement in K-12:
President Freeman Hrabowski, University of Maryland Baltimore County
President Emeritus Larry Faulkner, University of Texas at Austin

The two other keynote speakers provided leadership perspectives on faculty involvement with K-12 schools: Freeman Hrabowski, President, University of Maryland, Baltimore County (UMBC), and Larry Faulkner, President Emeritus, University of Texas at Austin.

Dr. Hrabowski addressed the fundamental question, posed by Wanda Ward, Deputy Assistant Director, Directorate for Education and Human Resources, NSF: "If a university makes a commitment to improve K-12 education, what are the implications for faculty who engage in this work?"

Dr. Hrabowski discussed the paradox that underlies this persistent question. In order to change faculty culture, we must change attitudes, and in order to change attitudes, we must change faculty culture. Why, for example, do we systematically discourage our brightest students from becoming teachers? "Should only those students who cannot excel be the ones we encourage to be teachers?" he asked. "We need smart people at every level of education [...] What does it take to get faculty colleagues to think differently about who becomes a teacher?" He took a broad perspective in addressing these issues, and challenged the Summit participants to see the entire STEM pipeline from K-12, to undergraduate education, to graduate education, and on to the faculty level. These are not problems that can be solved overnight, nor can they be addressed solely through the well-intentioned grant programs of NSF and ED. "True commitment," Dr. Hrabowski stressed, "means not only supporting someone getting a grant from NSF [or ED]; it means deciding to identify resources from the campus and other places to leverage the money that comes from NSF [or ED]."

Changes in faculty attitudes must take place at many levels. At UMBC, for example, K-12 involvement is recorded on annual reports of faculty activity, in an attempt to raise the visibility of this work on campus. This is a first step toward recognizing and rewarding this part of faculty work. Reporting, recording, and recognition also set the stage for establishing a community for those faculty who participate in work with K-12 schools. Dr. Hrabowski noted that "a key [to changing culture] is building community. Faculty who engage in this work need opportunities for robust dialogue with each other."

From his leadership perspective, Dr. Hrabowski concluded his remarks by sharing several lessons learned over the course of his work in this arena:

- Faculty work related to the STEM pipeline, and K-12 schools, needs to be presented to the academic leaders of a campus as often as possible. Such work needs to be mainstreamed into academic initiatives, not merely tucked away in a single department.

- Faculty and administrators need to celebrate the successes and decisions of STEM students who want to become teachers, in order to create a more positive climate for future educators.

- Helping K-12 teachers invariably gets faculty to think about their own teaching and pedagogy – something that is long overdue in higher education.

- Department chairs need to play the role of mentors and coaches in helping faculty succeed in their K-12 work, setting clear expectations and giving timely feedback.

- Data analysis is a valuable tool that can be used by departments and individual faculty members to better understand ways in which students are achieving intended learning outcomes, and ways in which they are not.

In his closing address for the Summit, Dr. Faulkner took the opportunity to herald the work of the National Mathematics Panel, and to illustrate how a long-term commitment to the improvement of STEM education can transform a university community. He used as his text, the example of the University of Texas at Austin's nationally recognized UTEACH program. UTEACH began a year before Dr. Faulkner became president, driven by an innovative and influential dean, Mary Ann Rankin (College of Natural Sciences). The project began, like many innovations, with a few key questions: Why did the university have such low productivity of STEM teachers? Why did so few STEM teachers end up staying in the profession? They approached the problem as a research question, almost an engineering question: Identify the barriers to getting STEM majors to consider a teaching career, and address them. Their analysis led to streamlining course structures and course sequences, while preparing students for state teacher certification with robust subject matter degrees. The UTEACH program resulted in increasing the number of teacher candidates, the diversity of these candidates, and retention in the profession.

Why has UTEACH been so successful? While Dr. Faulkner credited his colleague, Dr. Rankin, with the vision and the driving passion for the project, he also acknowledged that commitment to K-12 was one of the "themes" of his presidency. Under his leadership, the university took on substantial fundraising challenges to support the UTEACH program, and the faculty and administrators who made the program a success were celebrated and appreciated. Like Dr. Hrabowski, Dr. Faulkner embodies the type of leadership that starts to change culture on campuses in meaningful ways.

Both Dr. Hrabowski and Dr. Faulkner noted that it is a mistake to describe the current situation in the United States as a "STEM crisis," because in doing so, we reach for "quick fixes." Rather, both suggested that the issues require long-term attention from people who are committed to long-term solutions. In making reference to the soon to be published National Mathematics Panel Report, Dr. Faulkner challenged his audience to stop thinking about "averages" when it comes to education policy and performance. Comparing our students to international student populations often leads to the wrong conclusions. In reality, he said, there is a disturbing bipolar distribution of students in the

United States. This achievement gap is wide and growing wider every year. Higher education is a critical part of the long term solution.

Both Dr. Hrabowski and Dr. Faulkner acknowledged the difficulties that the STEM education community faces in trying to change culture and attitudes, but both demonstrated how strong, committed leadership can foster positive (and necessary) change.

Conclusions: Intellectual Merit and Broader Impact

The December Summit brought faculty together from two federally funded programs to share lessons learned and to help NSF and ED assess one particular aspect of the intellectual merit and broader impact of the MSP projects: the engagement of STEM faculty. A summary analysis of various participant contributions to the Summit suggests that the major findings fall into three separate but related categories:

- Building successful P-20 partnerships;
- Engaging faculty productively in STEM partnership work; and
- Recognizing the importance of research and evaluation.

Building Successful P-20 Partnerships

There was almost universal agreement among faculty participants at the Summit that the partnership model is crucially important for addressing the challenges of improving student learning in mathematics and science, and for constructing a strong, coordinated STEM education system. In his concluding panel remarks, Terry Millar (UW, Madison) commented that we must take a "systems approach" to this work. To transform P-20 education, we need to work simultaneously and collaboratively, not in a "divide and conquer" mode. Dr. Millar strongly urged that we need innovative partnerships to do this work, and that it requires faculty to move beyond their individual areas of expertise, a difficult role.

James Milgram (Stanford) noted during the closing panel that while we know a great deal about how to improve outcomes in mathematics for in-service teachers, it takes time. Partnerships under pressure of a "quick fix" are particularly vulnerable. He also noted that partnerships between universities and the most challenged school districts suffer from the systemic problems of those districts that make it virtually impossible to collect long-term data on student outcomes (a challenge for MSPs that will be discussed later under research and evaluation).

P-20 partnerships that are successful understand how to use the strengths of higher education institutions to help support K-12 schools. Many participants confirmed the importance of building community through partnerships – using collaborative processes

to develop summer institutes for teacher professional development, for example. There was general consensus that "true partnerships" are needed for the successful implementation of STEM education reform.

Engaging Faculty Productively in STEM Partnership Work

Of all the purposes of this Summit, the goal of engaging STEM faculty in partnership work was paramount. One of the most interesting aspects of the meeting was observing the extent of faculty interest in understanding how students learn. Many faculty described how their involvement in MSPs has deepened their knowledge and understanding of this area of study. For example, many sessions cited the National Research Council's *How People Learn, How Students Learn,* and *Taking Science to School*. Barbara Schaal (Washington University) reflected this excitement and interest in her closing panel comments when she noted that faculty have conceptual frameworks for their disciplines and logical sequences for how to teach content, but how are these then connected to how teachers and students actually learn? Dr. Schaal shared that instinct for investigation with many of the Summit participants. There was broad acknowledgment and fundamental agreement that STEM faculty had a lot to learn about how to *teach* mathematics and science, even if they were well-grounded in their disciplinary content. In fact, one key benefit of P-20 partnership work is the improvement of STEM teaching at the college level.

Thus, it would appear that one of the most important seeds for engaging faculty in this work seems to lie deep in the nature of their personal and professional identities – their own curiosity and need to know and learn through experimentation, investigation, and discovery. However, these processes must also be linked to institutional rewards and recognition, or even the best intentions will go unrealized.

Issues related to faculty rewards for engagement in MSPs and similar P-20 work was another strong and predictable undercurrent throughout the discussions. Acknowledging that the Summit participants were a biased sample, there was agreement that colleges and universities need to provide incentives and rewards to support faculty in this work at different stages in their careers. In the closing panel, Rich Cardullo (UC, Riverside) advocated for discussions at departmental levels, and with deans, provosts, presidents, and professional societies to generate the critically important institutional support for STEM faculty involvement in P-20 partnerships. He also noted that not all faculty members need to be engaged in the same ways. There is plenty of variation and diversity in this work, and faculty members should be encouraged to make their own decisions about how to become involved.

Throughout the Summit, faculty noted that their institutions and the professional societies need to give greater value and prestige to faculty efforts to improve K-12 schools and the training and professional development of K-12 teachers, including valuing research on this work that is published in education and disciplinary journals.

Faculty involvement in these initiatives should not be limited to direct service to teachers or schools. For example, a number of Summit participants noted that STEM faculty must also step forward and become involved in policy discussions around issues such as state standards, testing and assessment, and teacher certification. Again, not all faculty would find these roles compatible with their personal interests or professional career trajectory; however, there was consensus that faculty should be recognized and rewarded for their participation in committees, task forces, and advisory boards in order to help shape and inform broader local, state, and/or national agendas for STEM education reform.

Recognizing the Importance of Research and Evaluation

There was general agreement that NSF and ED's MSP agendas are critically important in helping to fulfill the National Science Board's goals of:

- Ensuring coherence in STEM learning; and

- Ensuring an adequate supply of well-prepared and highly effective STEM teachers.

However, what distinguishes the MSP projects from other policy initiatives is the charge from both NSF and ED to systematically study the work that the projects are doing, using recognized research and evaluation tools to gain new knowledge and understanding. While evidence-based inquiry has been an important feature of the MSP projects from the beginning, there was considerable discussion during the Summit about why this objective has been so difficult to accomplish.

Research and evaluation are essential components of each of the MSPs, yet, as Dr. Milgram observed during his summary panel comments, various systemic problems in school districts often make it a challenge to conduct longitudinal studies of student outcomes. Others noted the same data challenge exists in higher education. In addition, for STEM faculty in particular, their knowledge of social science research is a limiting factor, as well as lack of recognition for this type of scholarship. This reinforces a message given by a number of participants, that the involvement of social scientists in the MSP effort would significantly enhance the work.

Yet as problematic as it is to attempt systematic research and evaluation of partnership projects with so many "moving parts," new knowledge has been generated, new models have been tested, and rigorous research has generated evidence to support project hypotheses. For example, there is strong evidence that science teachers need to know and understand the basic unifying principles that cut across the sciences. Teachers who can illustrate scientific principles through experiments in the classroom and inquiry-based instruction are more effective teachers. Similarly, mathematics teachers who understand the fundamentals of mathematics and who tie problems to the real world are more effective teachers. Yet, these research findings still need to be implemented in real schools, with the real constraints of budget, personnel, politics, policies, and regulations. These "non-lab" real-world environments where reforms are implemented present challenges for the research and evaluation agenda of MSPs.

The Summit participants were quick to recognize that there is much variation in "what works" in different situations and contexts. As Dr. Cardullo stated in his closing remarks, "MSPs tackle a local problem, but are charged with informing what is happening at the national level." Dissemination is an important priority, as is continuing support for rigorous research and evaluation. Dr. Cardullo also challenged Summit participants to look beyond the limitations of the present: "We are still waiting for the next 'big question' to come out of the MSPs," he said. "We have lots of ongoing research and analysis of data and outcomes which will guide what comes next. The next 'big thing' may come from someone in this room or elsewhere. If we are truly interested in transformative research in education, we cannot be afraid of the next big question!"

Appendix E
MSP Site Visits

Projects Visited

The first site visit took place on November 3-4, 2006 when two members of the CASHÉ project team attended the annual statewide institute of the Partnership for Reform in Science and Mathematics (PRISM) in Georgia. As one of the strands of research for CASHÉ is higher education faculty engagement, project team members were invited to observe and participate in PRISM's annual statewide institute in order to gain insight into the nature of faculty participation in a comprehensive MSP project.

Over the two-day period, a total of 51 college and university faculty, P-12 teachers, project staff, campus administrators, and representatives from state-level educational agencies (e.g., department of education, university system) were involved in a series of one-hour focus groups and individual interviews with CASHÉ. The vast majority were science and mathematics faculty members from one of four participating colleges and universities in PRISM (Armstrong Atlantic State University, Georgia Southern University, Georgia State University, and the University of Georgia).

On May 22-23, 2008 and June 4-5, 2008, CASHÉ conducted its second and third of six site visits to MSP projects. Site visit teams went to the Math Science Partnership of Greater Philadelphia (MSPGP) and FOCUS at the University of California-Irvine. The purpose of these visits was to examine processes and outcomes related to institutional change in the context of MSP partnerships across a variety of project types and institutional types. MSPGP was selected because it is a complex partnership involving a diverse range of two-year and four-year higher education institutions, has a centralized project management structure, and, as an outgrowth of the partnership, has created a regional STEM compact and non-profit entity to sustain the project's work and leverage additional funding. FOCUS was selected because it is a mature MSP project (Cohort I) nearing its completion, provides a single institution context, involves a research university, has used a variety of strategies for engaging higher education faculty, and is heavily invested in STEM teacher preparation, including the CalTeach initiative.

The fourth site visit occurred September 22-23, 2008 to the Appalachian Math Science Partnership (AMSP) centered at the University of Kentucky. AMSP helps strengthen and reform education in mathematics and science in pre-K through grade 12 classrooms in participating districts in Kentucky, Tennessee, and Virginia. The AMSP program seeks to demonstrate improved student achievement in mathematics and science through the support of partnerships that unite the efforts of teachers, administrators, guidance counselors, and parents in local schools with administrators and faculty at area colleges and universities. AMSP's goals are to eliminate the achievement gap in the Central Appalachian region and to build an integrated elementary, secondary, and higher education system. The higher education partners include: Eastern Kentucky University, Kentucky State University, Morehead State University, Pikeville College, Prestonsburg Community College, Union College, University of Kentucky (lead institution),

University of Virginia College at Wise, University of Tennessee, and Somerset Community College. The AMSP project was chosen because it is a large rural project involving multiple higher education partners and types, shows a strong commitment to STEM teacher education course and program redesign and recently created a new Associate Provost for Educational Partnerships position at the University of Kentucky.

On October 14-15, 2008 the fifth site visit was conducted in Virginia when site visit team members participated in an NSF Institute: Preparing Virginia's Mathematics Specialists. Virginia Commonwealth University, in conjunction with the Virginia Mathematics and Science Coalition, two university core partners (Norfolk State University and the University of Virginia) and 5 school district core partners offer an NSF Institute to prepare K-5 middle school Mathematics Specialists as part of their MSP grant. The goal of the Virginia MSP is to prepare teachers to meet the requirements for licensure as a Mathematics Specialist by offering them the opportunity to earn Masters Degree in mathematics content and educational leadership. Participants are recruited from diverse populations in participating school systems which have agreed to place teacher-participants in Mathematics Specialists positions upon graduation. This project was chosen because it is an institute project, faculty work across disciplines in training the teachers and it has a strong partnership with the local school districts.

The sixth and final site visit took place at the Rocky Mountain Middle School Math Science Partnership: "15 Months to Highly Qualified" (RMMSMSP) at the University Colorado at Denver (UC-Denver). The RMMSMSP partnership is comprised of three core partner Colorado school districts, Jefferson County, Brighton, and Mapleton, and the University of Colorado at Denver (CU-Denver) as the lead institution. Supporting partners include the University of Denver (DU), the Metropolitan State College of Denver (MSCD), and the Colorado State University (CSU) with affiliations to Ft. Lewis College, the Front Range Board of Cooperative Educational Services, and four school districts: Adams County 14, Englewood, Elizabeth, and Gilpin County. Over the five years of the project, approximately 600 teachers have been involved and 26,400 students in grades 6-8 will have been impacted. RMMSMSP will increase student achievement in high quality mathematics and science coursework and reduce the achievement gap between minority and non-minority middle school students by focusing the combined expertise of seven school districts and four higher education institutions on implementation of challenging curriculum taught by highly qualified and diverse teachers in grades 6-8. This project was chosen because it is a multi-state partnership working across multiple school districts and with multiple universities. The focus on minority education and student achievement also enhanced the value of choosing this site.

Site Visit Framing Questions

What is the history and context of the MSP?

1. What kinds of relationships and programs were in place, before the MSP began, to support P-20 STEM education? Were there barriers to working together?
2. Were there founding fathers and mothers for this project? Where in the university organization were they?
3. Was there an institutional motivator for change – an internal or external context that needed attending to?
4. How do the relationships that have developed through the MSP differ from previous partnership arrangements?

In what ways have institutions leveraged institutional change through the MSP?

1. Was there a theory of action for this MSP? What were the design specifications? Was the MSP formed with something other than a "crossing our fingers" hypothesis?
2. How well did the campus(es) originally understand that the MSP was expected to have an impact toward change?
3. To what extent is the MSP currently isolated or connected to other STEM initiatives/reform efforts on campus? What other factors have been at play in addition to the MSP? Are there synergies?
4. Has the development of the MSP changed the types of faculty being recruited, the messages they receive about the institution, and what it values?
5. How would you describe the change that has occurred on the campus(es) as a result (in whole or in part) through the MSP? Include curriculum and pedagogy changes and any changes in the level of "shared ownership" for the preparation of K-12 teachers.

What body of evidence is there to support the change described above in II. 5.?

1. What data have been collected and what do they show?
2. How would different groups describe the outcomes of this MSP?
3. Is there ownership and buy-in at high levels in the campus(es)? How do you know that such commitment is independent of particular individuals?
4. Is this work valued on campus? How do you know?
5. What structures and resources are now in place to support collaboration in P-20 STEM education that were not present before the MSP? Have faculty in certain areas been more supported in P-20 involvement than others? If so, what factors account for these differences?
6. How have values and beliefs changed as a result of the MSP, and how do you know?

To what extent are these changes institutionally sustainable beyond the life of the MSP?

1. Will the partnerships established by the MSP persist after NSF funding ends? How do you know?
2. What parts of the MSP program have been institutionalized through budget? Through organizational changes? Through new hires?
3. The lowest level of sustainability is maintaining interventions; the second level is sustaining policies; the highest level is establishing new norms, behavior and choices. Where do this partnership's outcomes seem to fit, especially for IHE faculty in STEM disciplines?

Appendix F
Knowledge Dissemination Activities

Over the course of the grant, project staff (and affiliates) gave the following CASHÉ related presentations at national meetings:

Presentation Title	**Meeting**	**Date**	**Presenters Affiliated with CASHÉ**
Studying Higher Education Change and Sustainability through MSP Course and Curriculum Developments	MSP Evaluation Conference	October 2006	Spencer Benson (Advisory Board)
Opportunities for New Faculty Identities	Association of American Colleges and Universities (AAC&U) Faculty Work and the New Academy Meeting	November 2006	Danielle Susskind (Graduate Research Assistant)
K-16 Policy Environments: Taking the Bitter with the Better	Association for the Study of Higher Education (ASHE) Annual Meeting	November 2006	Patricia Maloney (Former Project Manager), Jim Hamos (NSF Project Officer), Don Langenberg (Advisory Board)
Making Good on our Word: STEM Faculty and K-16 Partnerships	Association for the Study of Higher Education (ASHE) Annual Meeting	November 2006	Patricia Maloney (Former Project Manager), Penelope Earley (Advisory Board)
Transforming Faculty Roles and Reward Systems in MSPs into Sustainable Practice in Higher Education	MSP Learning Network Conference	January 2007	Nancy Shapiro (Principal Investigator), Jennifer Frank (Project Manager)

Presentation Title	Meeting	Date	Presenters Affiliated with CASHÉ
Making Good on Our Word: STEM Faculty and K-16 Partnerships	American Association of Colleges for Teacher Education (AACTE) Annual Meeting	February 2007	Patricia Maloney (Former Project Manager), Penelope Earley (Advisory Board)
Studying Higher Education Change and Sustainability Efforts in the Context of PK-16 Partnerships	American Association for Educational Research (AERA) Annual Meeting	April 2007	Nancy Shapiro (Principal Investigator), Jennifer Frank (Project Manager), Danielle Susskind (Graduate Research Assistant)
If We Build It, Will They Come? The Case for Structural Change to Support STEM Education Reform	Association of American Colleges and Universities (AAC&U) Annual Meeting	January 2008	Nancy Shapiro (Principal Investigator), Jennifer Frank (Project Manager)
STEM Faculty Engagement in P-20 Partnerships: A Conflict of Interest?	Association of American Colleges and Universities (AAC&U) Academic Renewal Conference	April 2009	Danielle Susskind (Graduate Research Assistant)
Lessons Learned from the Change and Sustainability in Higher Education (CASHÉ) Project	APLU SMTI Leadership Collaborative Retreat	January 2010	Nancy Shapiro (Principal Investigator)
Institutional Change and Sustainability: Lessons Learned from the MSPs	MSP Learning Network Conference	January 2010	Nancy Shapiro (Principal Investigator), Jennifer Frank (Project Manager)