Effect of STEM Faculty Engagement in MSP—A Longitudinal Perspective

A Year 4 RETA Report

May 2008

Prepared for:
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Table of Contents

Introduction 1

The Math and Science Partnership (MSP) program is a major national research and development effort that supports innovative partnerships to improve K–12 student achievement in mathematics and science. Deep engagement of science, technology, engineering, and mathematics (STEM) disciplinary faculty is a hallmark of this program. The program posits that disciplinary faculty hold the knowledge that K–12 teachers need, and that if faculty are substantially involved, the chain of professional knowledge will be strengthened and result in improved student achievement. Westat's research, evaluation, and technical assistance (RETA) grant aims to examine this assumption empirically. Specifically, we are asking how STEM faculty are engaged in MSP. Does the involvement make any difference in enhancing teacher quality and increasing student achievement? And are there particular circumstances in which certain types of involvement contribute more or less than others on these dimensions? In essence, we ask what works, for whom, and under what circumstance through the following six research questions:

1. What methods (i.e., strategies, practices, and policies) are being used by the projects to engage STEM faculty in their activities, and how do these differ by type of institution of higher education (IHE)?
2. What levels of involvement are garnered by various methods at different types of IHEs?
3. To what extent does STEM faculty involvement contribute to increases in K–12 teacher content and pedagogical knowledge?
4. To what extent does STEM faculty involvement contribute to student achievement?
5. What are the policy implications for engaging STEM faculty?
6. How does faculty involvement evolve, and does it appear to have the ability to be sustained?

Westat's study is funded over four years and consists of two major components: case studies of eight MSP projects from three cohorts, and an analysis of data collected from the MSP Management Information System (MIS) on all MSP intervention projects. Because the annual report of this project is due at about the same time that validation of MIS data is completed, our analysis of MIS data—especially the student achievement data—has had a one-year lag. The same delay occurs for the secondary analysis of the annual reports and evaluation reports from the case study projects. In order to address this issue, we requested and were granted a one-year no-cost extension. As a result, the year 4 report will only present findings from case studies of eight MSP projects. The final report will be submitted in year 5 and include findings from all components of the study.

The study approach in year 4 continues to describe different components related to STEM faculty involvement. Specifically, we operationalize the research questions into four questions. The operational questions represent an evolution of our thinking based on our experiences in this study. Compared to the original questions, we expanded inquiries about impacts on STEM faculty themselves as well as on the institutions both at the K–12 and IHE levels. Of the four operational questions, the first two are designed to understand the nature and scope of STEM faculty involvement and the last two are intended to address the effects of such involvement, which is the focus of our study.

- What has the project done to engage and support STEM faculty involvement?
- Has there been any change in the number of STEM faculty, extent and variety of involvement, and nature of collaboration between STEM faculty and other participants?
- What are the effects of STEM faculty engagement on teachers, students, and STEM faculty themselves?
- What are the effects of STEM faculty engagement on K–12 districts and IHEs? Does STEM faculty involvement as well as its effects appear to have the ability to be sustained?

Our findings are presented in the following sections:

- Year 4 data collection and analysis methodologies,
- Case study findings, and
- Implications for future study.

Year 4 Data Collection and Analysis Methodologies 2

This section describes our approach to the site visit component of the case studies. Remaining analysis of MIS data and secondary analysis of case study and non-case-study projects will be conducted during the period of no-cost extension.

The eight case study projects were selected based on a review of proposals for a relatively high level of STEM faculty participation in the projects and for their willingness to participate in this RETA project. Elements for a high level of STEM faculty participation are often indicated by an important role of STEM faculty envisioned by the project in the proposal, the types and levels of STEM faculty engagement proposed, and the number of faculty who had already signed up as participants. Because this grant was awarded in the off-year cycle between cohorts 1 and 2, most of the case study projects we selected are in cohorts 2 and 3 so that we could follow their development from the very beginning. Using data from the MIS as a retrospective check, we found that STEM faculty from our eight case study projects are representative of the MSP projects in aspects such as demographics, tenure status, and faculty rank; they differ in their higher level of STEM faculty involvement: 46 percent of STEM faculty in case study projects were involved in MSP for more than 200 hours, as compared to 26 percent in all MSP projects in the baseline years.

Table 2-1 provides information about characteristics of all eight case study projects. Two projects focus on mathematics, four on science, and two on both mathematics and science. The projects include one MSP comprehensive project, five targeted projects, and two institute projects.[1] For the lead institutions, four are classified under the Carnegie classification system as Research University (very high research activity), one as Research University (high research activity), one as Doctoral/Research University, and two as Master's College or University (larger program). Six of the IHEs are public and two are private. Geographically, they are located in the East, Midwest, South, and West. In addition, the lead IHEs in all but two projects are working with 2 to 10 IHE core partners. The number of K–12 districts range from 2 to 29, with an average of 10.

[1] Comprehensive projects implement change in mathematics and science educational across the K–12 continuum. Targeted projects improve K–12 student achievement in a narrower grade range or disciplinary focus in mathematics and/or science. Institute projects focus on improving middle and high school mathematics and science through the development of school-based intellectual leaders and master teachers.

We conduct annual site visits to the eight projects to track the changes and development of faculty engagement over time. Site visits in the first two years primarily focused on what was happening with STEM faculty at IHEs. In the third and fourth years, we further broadened the scope of examination to the effects occurring among teachers, students, and K–12 schools as a result of STEM faculty involvement. While most of the site visits have been conducted in the fall during the academic year, at least one was done in the summer to allow us to observe the summer institutes where the project activities are most intense.

Site visits in year 4 were conducted by teams of two researchers: one from Westat and one by an external STEM disciplinary faculty member (Appendix A) in late fall 2007 and early spring 2008. To maintain consistency and build on knowledge from previous visits, the Westat site visitors have been the same for each project throughout the entire study. The three-day site visits included both interviews (project leadership, STEM faculty members, department chairs, project evaluators, inservice teachers leaders and teachers, principals, and district content/curriculum specialists) and classroom observation of STEM faculty and K–12 teachers with whom STEM faculty have worked (Table 2-2). Semi-structured interviews and observations were guided by protocols (Appendix B). In order to capture evidence about impacts, we included interviews of project evaluators and K–12 district content/curriculum specialists, where possible.

Table 2-1. Characteristics of the case study sample

Aspect	P1	P2	P3	P4	P5	P6	P7	P8
MSP cohort	1	2	2	2	3	3	3	3
MSP project type	C	T	T	T	T	T	I	I
Content focus	M/S	M	S	M/S	S	S	M	S
Institution type of lead partner								
■ Carnegie classification								
Research University (very high research activity)	X				X		X	X
Research University (high research activity)		X						
Doctoral/Research University				X				
Master's College or University			X			X		
■ Ownership								
Public	X	X	X		X	X	X	
Private				X				X
■ Location								
East				X		X		X
South		X						
Midwest					X			
West	X		X				X	
Total number of IHE partners	1	2	5	2	5	4	10	1
Total number of K–12 district partners	3	15	29	10	8	2	10	17

C=Comprehensive, T=Targeted, I=Institute; M=Mathematics, S=Science.
Data source: MSP MIS, Case studies.

Table 2-2. Site visit activities in year 4

Activity	Respondent	Number
Interviews	PI/co-PI/PD	15
	IHE STEM faculty	28 (individual), 1 (group)
	IHE education faculty	7
	IHE department chairs	4 (excludes 3 PIs who are currently serving as chairs)
	K–12 teacher leaders/teachers	36 (individual), 1 (group)
	K–12 principals	14
	K–12 district content/curriculum specialists	9
	Project evaluators	9
	Others (i.e., project staff)	2 (group)
Observations	IHE preservice/undergraduate classes	3
	K–12 math and science classes	22
	Others (i.e., project strategic planning meeting)	1

PI = principal investigator; PD = project director.

The data obtained from the year 4 site visits provide researchers with a thorough understanding of STEM faculty involvement and its potential effects in each project as well as across projects. Essentially, we use two forms of triangulation. The first is within each project, whereby evidence is triangulated from interviews, observations, and document reviews. The second occurs across projects, whereby evidence is compared and contrasted in the context of each project.

Case Study Findings 3

In this chapter, we first revisit the institutional environment in which STEM faculty engagement is taking place. Then, we present findings related to each of the four operational questions. For each section, we begin with a summary (in bold), followed by discussion of detailed findings. Because the findings are derived from site visits over the past four years in a cumulative fashion, we pay special attention to the pattern of changes (or a lack of change) over time. In presenting case studies, care has been taken to remove individual, institution, and project identifiers to protect the confidentiality of the respondents.

3.1 Institutional Environment for STEM Faculty Involvement

Traditional reward structures and faculty perceptions about the status associated with different types of engagement are considered major barriers for faculty involvement in most MSP-like endeavors. While the majority of the IHEs recognized service or outreach, such activities are generally considered to be a distant third in priority after research and teaching. This hierarchy presents a serious institutional problem and a major roadblock to involving faculty from the STEM disciplines. Some institutions specifically discourage junior faculty from participating in these activities so that they do not have to sacrifice time that could otherwise be spent on research.

Other conditions are critical to STEM faculty involvement. At the IHE level, such conditions may include previous experience working with K–12 sectors and hiring practices. At the K–12 level, a key issue is the support from the leadership. State and local policies, coupled with changes in infrastructure and funding, may also enhance or impede the implementation and impact of MSP projects and STEM faculty involvement.

In this section, we describe the contextual variables in the IHE and K–12 environment, as well as external factors that existed prior to or are taking place simultaneously with MSP but may affect STEM faculty involvement with special attention to IHEs' tenure and reward policies. Changes in the K–12 and IHE environments as a result of STEM faculty engagement will be discussed in Section 3.5.

3.1.1 IHEs

Tenure and Reward Policies

Our literature review suggests that obtaining the involvement of disciplinary faculty in education reform efforts is challenging throughout higher education. The most prominent reason is that promotion, rank, and tenure committees do not weigh research, teaching, and service equally. Instead, sponsored research and the publications that emanate from it combine to create the reward system's holy grail at IHEs (Kuh, 1998). Tenure and reward policies are one of the main foci of our investigation, because they are often considered the biggest hurdle to creating a K–20 learning community through partnerships. Our focus is not only on how such policies are articulated at the university (macro) level, but also how they were implemented at the department (mezzo) level, and perceived by the STEM faculty themselves (micro-level).

Hora and Millar (2007) described a typical procedure for tenure review. First, a department personnel committee reviews personnel files and submits a recommendation. Next, the department chair makes an independent evaluation, followed by recommendations submitted by the personnel committee of the college, the dean, and the president. Although specific language varies, the criteria for tenure often include the following: 1) professional preparation, 2) teaching effectiveness, 3) contributions to the field of study, including publications, and 4) contributions to the university and community.

Research and sometimes teaching are the principal paths to promotion. Considered to be a distant third path, outreach or service, sometimes referred to as "other contributions," continues to be used to define MSP involvement in most cases. The emphasis on research productivity reflects a prevailing IHE culture that goes beyond the control of individual IHEs. To survive in a highly competitive IHE environment, large research universities want to maintain their edge and smaller colleges strive to become research universities, and research productivity often becomes a critical element in the equation.

Of the eight lead IHEs, the policies of seven contain language recognizing service and/or outreach (Table 3-1). Five recognize publications arising from such activity in the sense of the scholarship of teaching and learning. For example, one IHE characterizes the activity as "outreach scholarship" as long as the following conditions are met: 1) there is a substantive link with significant human needs and societal problems, issues or concerns; 2) there is a direct application of knowledge to significant human needs and societal problems, issues, or concerns; 3) there is utilization of the faculty member's academic and professional expertise; 4) the ultimate purpose is for the public or common good; 5) new knowledge is generated for the discipline and/or the audience or clientele; and 6) there is a clear link or relationship between the programs or activities and appropriate academic unit's mission.

Table 3-1. MSP involvement characterized by IHE tenure and reward policies (case study projects)

Policy aspect	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Outreach/service	X	X	X	X	X		X	X
Scholarship of learning and teaching		X	X	X	X	X		

C = Comprehensive, T = Targeted, I = Institute.

SOURCE: Case studies.

However, university policies are often implemented differently at the department level. Many pointed out that "this is where the change is taking place," because department chairs prepare the dossier for the review committee. In at least two instances, department policy statements noted that the department generally avoids major service demands on untenured faculty and that leadership in outreach/service is not part of the criteria for tenure. However, the section on appointment to full professor mentions the need to demonstrate significant accomplishments within the department, university, and professional societies, as well as outreach to the community including civic duties related to mathematics and science education. It is not surprising that most of the faculty members participating in the MSP project are tenured, so the younger, less established ones do not have to "sacrifice" time that would otherwise be spent conducting research. In fact, one project director was told that tenure-track faculty are "off limits."

Many respondents observed the following patterns: junior faculty must focus on teaching and research first; once tenure is achieved, the balance of responsibilities may change, as faculty either focus entirely on research or become engaged in teaching or service. As a result, tenured faculty have much more freedom to decide how they allocate their time and resources.

The ultimate goal of these policies is to influence faculty. When asked whether they would be rewarded at their institutions for participating in an MSP-type activity, a minority of the STEM faculty thought that participation would be viewed positively; most felt it would be either tolerated or ignored. "What reward system?!" faculty from one project reacted. Some feel that the most that can be hoped for is for deans and department chairs to broadcast a message indicating "there is no reward for doing this, but it is okay for you to do it." Many faculty would not even think to include MSP participation in their review.

Most faculty members believe that teaching and service will never make up for a lack of research while large research grants can eliminate the need for any formal classroom teaching or service. However, it also appears the distinction is not necessarily set in stone. One faculty member told us, "It would be up to *me* to characterize it and present it to the university." In his case, MSP work was defined by the department as service, especially the professional development piece; preservice teaching and curriculum design fell under teaching and curriculum development, but if the MSP work comes out in peer-reviewed journals, it is classified as scholarship.

Other Contextual Factors at the IHE Levels

Few IHEs in the case studies were complete strangers to working with K–12 prior to MSP. Some had a record of outreach activities, some harkened back to their roots as land-grant institutions or teachers' colleges, and others have received state funding to work with local school districts. For example, in one large IHE, STEM faculty involvement has been funded through various state, federal, and foundation initiatives over the past 30 years. Prior to MSP, the state subject-matter projects in mathematics and science funded a lot of the outreach activities by STEM faculty. Currently, another state initiative was augmented with funds and activities from MSP to provide training to teacher leaders and future teachers by paying them to work as classroom apprentices under mentor teachers. We see ample evidence that the MSP project has built on the shoulders on other previous efforts or has led to further funding opportunities to engage STEM faculty in educational reforms.

Other policies or mechanism in place may contribute to STEM faculty engagement. One university has an infrastructure that long predates MSP, guaranteeing two faculty members per STEM department who are committed to work half time on disciplinary teaching and research, and half time on pre/inservice teacher training. A non-case-study project provided another example (Hora and Millar, 2007). Funded by a grant from the Carnegie Corporation, the Annenberg Foundation, and the Ford Foundation, the university hired five new faculty members in arts and science departments to both tenure-track and three-year lecturer positions, all of which are guaranteed funding by the university after the grant expires. These faculty pursue scholarship and teaching activities in their disciplines while focusing on pedagogical issues, teacher training, and K–12 education. Most have special Memoranda of Understanding for their tenure and promotion guidelines to explicitly account for the pedagogical orientation of their research and levels of service. Furthermore, they generally have reduced teaching loads, as their time has been "bought out" by the grant. In another project, the fact that MSP course teaching counts as "part of the load" has helped with the faculty recruitment. This is noteworthy in its own right, because it has established the precedent within the university.

3.1.2 K–12 Districts

As shown in Table 3-2, case study projects work with multiple K–12 partners. Projects with a smaller number of K–12 partners tend to be located in urban and suburban environments, while those that involve a large number of districts are often located in rural areas.

Table 3-2. MSP involvement with K–12 partners (case study projects)

Partner characteristic	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Number of K–12 district partners	3	15	29	10	8	2	10	17
Characteristics of K–12 partners								
Urban	X			X	X	X	X	
Suburban		X	X	X	X		X	X
Rural		X	X		X		X	

C = Comprehensive, T = Targeted, I = Institute.

SOURCE: MSP MIS; case studies.

In general, the MSP projects enjoy a collegial relationship with their K–12 partners. As in any partnerships, there are a range of reactions even within a project—some are more active and engaging, while others have problems. One project was primarily designed to serve the local community—a large urban district. The main responsibility of the school district was teacher recruitment. However, the project leadership was disappointed with the level of commitment from the school district. Because the district did not recruit enough teachers, the project ended up serving teachers from a wide range of districts in the region, many of which are in rich suburban areas.

Leadership from another project expressed deep frustrations in working with the school districts. First, the city department of education did not provide any support with recruitment because the people who endorsed the project were gone. Second, the districts did not respond with sufficient buy-in. Some viewed the project as competition to the local offerings in professional development. This response is not unexpected given the increasing emphasis on and support for district-sponsored professional development. It also raises a general question about whether IHEs should offer PD of their own design or tailor their PD to district specifications to be able to obtain district support. The PI and project director had to call all of the eligible families to encourage their children to attend the summer camp, but they were still one-third short of the projected enrollment in the first year. The project provided $5,000 per teacher for participation, but many teachers were still not interested. The issues with K–12 districts may be related to turf. Some noted that districts only wanted IHE participation in projects that they controlled and were uncooperative if they did not have control. It should also be noted that school districts that do not respond post-funding with sufficient buy-in were often not consulted pre-funding with sufficient detail or planning.

Another key issue is principal and administrative support. Many projects offer professional development for principals or include them as part of the learning community. According to one PI, “The toughest thing we have to deal with is the involvement of the principal.” Principal support is uneven, but the project does not have much leverage over principals—some attend the training, others may not. Some participants are actively involved and supportive, while others may attend but not be committed. The uninvolved principals may not interfere with the teacher leaders, but they do not provide any support either. As one PI stated, “It is like night and day when the principal is involved.”

Finally, STEM faculty involvement and MSP projects are implemented as K–12 districts are dealing with challenges that often go beyond what the projects can do. One of the challenges is teacher turnover—especially for urban districts. One STEM faculty member spoke of the turnover that had occurred in the school she worked with: other than the social worker, she was the only person who was consistently a part of the team for the five years of the project. The school had four science teachers, two for eighth-grade and two for seventh-grade. Only one of the four science teachers stayed with the team for the two years she worked with the school. In the second year, the district hired a science coordinator, but that person was let go. The STEM faculty member was disappointed about her contribution, “I don’t think I accomplished anything with science. There was too much to overcome. What I was trying to do came to nothing. The students got nothing.” In another project, a bitter, multiyear state control created so much teacher turnover that more than

60 percent of teachers across all fields were employed with emergency permits by the time local control was fully returned.

3.1.3 Other External Factors

Other external factors can either enhance or impede implementation and the impact of MSP projects in general and STEM faculty involvement in particular. For example, all projects involved are facing increasing pressure from their states to enforce standards and improve student achievement.

In the past, we heard about influences from mandatory test requirements, state-developed content curriculum standards, and initiatives to increase the number of mathematics and science teachers. Of course, the No Child Left Behind state assessments and the requirement for "highly qualified teachers" are of paramount priority for teachers and principals. While many of these influences may create momentum for the MSP, others can be counterproductive. For instance, adoption of new curricula in other subject areas may take away time and attention from science. It appears that in some districts, the "math wars" have been revived, posing future threats to the underlying principles of many MSP projects.

State funding may also fluctuate. For one project, while the state cut back funding for university outreach activities, it provided additional funding for teacher preparation programs in STEM fields. The multi-campus university system was trying to increase the annual production of credentialed mathematics and science teachers from 250 to 1,000 by 2010 in response to the critical shortage of highly qualified STEM teachers in the state.

One state recently introduced an accountability system that requires STEM faculty involvement in supervising preservice student teaching. Last year, based on its MSP model, the lead IHE received a state grant to create a site for promoting K–12 mathematics and science education, including collaborative work on curriculum and summer classes for teachers. The project leadership used essentially the same model as MSP for science and created a crossover mechanism that reduces the training requirement for teachers who have already gone through MSP workshops.

Faced with poor performance of high school students on the state exams, a large school district (municipal department of education) introduced an empowerment movement where schools can become semi-autonomous. The autonomy includes hiring and firing, controlling the budget, and training principals, coupled with high accountability, the provision of high-quality materials in impoverished schools, and alignment of professional development with instructional objectives. Half of the schools working with the project belong to this category because they have the freedom to choose professional development providers. In addition, a large number of teachers came to teaching from other careers, creating a huge demand for training. Similarly, because some of the schools the MSP projects are assisting have large amounts of Title I and Title II federal and state grants for professional development, some MSP projects have been able to tap some of these funds to develop customized fee-for-service professional development.

3.2 Operational Question One: What has the project done to engage and support STEM faculty involvement?

Although tenure and reward policies are critical to STEM faculty engagement, most MSP projects were not specifically designed to tackle those issues. Nevertheless, there are a number of effective strategies a project can use to increase STEM faculty engagement in the absence of changes in tenure and reward policies. At the project level, both extrinsic and intrinsic incentives need to be created. The former may involve providing release time and stipends for faculty members, and the latter often include providing professional development to faculty to enhance their understanding of K–12 perspectives and pedagogical issues, building partnerships among participants, as well as demonstrating sensitivity and flexibility to faculty needs.

Extrinsic incentives are well understood, as all of the case study projects offer stipends and five provide release time. These incentives were established at the beginning of the projects and have remained consistent over time. The intrinsic piece, especially for the project to make the case and create intellectual connection for substantive STEM faculty work with K–12 teachers, is often underestimated. While most projects recognized the importance of building partnership early on, many projects have had a steep learning curve throughout the years about the value of providing professional development for STEM faculty, as well as demonstrating sensitivity and flexibility to their needs. Case studies also highlight the need for projects to use evidence-based evaluation to guide STEM faculty engagement.

As pointed out in the previous section, involving STEM faculty in K–20 educational reform efforts is challenging. The most prominent reason for this difficulty is the lack of incentives. Colbeck (1994) found that the reward system is a powerful motivator of faculty behavior. Classic behavioral theories argue that there are two fundamental human needs—biological and psychological (Herzberg, 1966; Maslow, 1954). Intrinsic motivation is related to psychological needs, while extrinsic motivation is related to the environment and fulfill biological needs. Successful incentives have to appeal to both intrinsic and extrinsic human needs. Although the majority of the participating STEM faculty are highly motivated, they still need additional incentives to sustain a high level of motivation. In other words, self-motivation is not enough, especially when projects require multiyear extensive involvement from the faculty. In fact, the issue of incentives may be even more critical to further expansion of STEM faculty engagement, especially as the current IHE reward structure and tenure policies are not conducive to MSP-like activities.

Although tenure and reward policies are critical to engaging STEM faculty, most MSP projects were not specifically designed to tackle that directly. Nevertheless, there are a number of effective strategies a project can use to increase STEM faculty engagement in the absence of changes in tenure and reward policies. In this section, we discuss specific tools available for projects to support and engage STEM faculty. We have found through case studies that motivation for STEM faculty to become engaged in the multiyear life of a project appears to hinge on two necessary and entwined conditions. The first condition is extrinsic and clear. Projects need to provide adequate course release and/or summer salary for participating STEM faculty. The second condition for STEM faculty engagement is an intellectual connection, that is, the project must make the case for the need for substantive STEM faculty work with K–12 teachers. This is an intrinsic and perhaps underestimated condition. Using evidence from the case studies, we continue to explore project strategies to engage STEM faculty (Table 3-3).

Table 3-3. Project efforts to engage and guide STEM faculty (case study projects)

Effort	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Using extrinsic incentives								
Summer stipends	X	X	X	X	X	X	X	X
Release time	X	X	X		X	X		
Using intrinsic incentives								
Professional development for STEM		X	X	X	X	X	X	X
Building partnership		X	X	X	X	X	X	
Sensitivity and flexibility			X		X	X	X	
Using evidence-based evaluation	X		X					

C = Comprehensive, T = Targeted, I = Institute.

SOURCE: Case studies.

3.2.1 Providing Extrinsic Incentives

We found that all eight projects offer stipends and five provide release time as extrinsic incentives. These incentives were established at the beginning of the projects and have remained consistent over the period of MSP.

The stipends often are for one or two months during the summer if the activities involve summer institutes, although one PI was adamant that the support should be for three months to make it easier to secure faculty commitment. For one project, stipends were larger in year 1 when courses were being developed and smaller for the rest of the years when only modifications and adjustments were needed.

Involvement during the school year is normally compensated by release time and/or stipends. Of the three projects that do not provide release time, two are Institute projects whose primary activities occur in the summer. For the third project, faculty participation was originally planned to occur in the summer. However, as many teams decided to conduct at least some of the training during the school year, the incentive scheme did not change and faculty continue to be reimbursed with stipends but not release time.

In terms of the amount of release time, one course release per term seems to be the norm. For one project, MSP teaching counts as part of the teaching load; in some others, release time has to be negotiated. For example, a department chair was able to arrange for course buy-outs for faculty after making the case with administration because in his institution, release time is normally possible only in research-related situations. Policies may vary within projects. While faculty from a lead institution may receive course buy-out, members from non-lead institutions often do not receive course release.

While recognizing incentives, we do not mean to ignore the element of altruism. In fact, many participating STEM faculty suggested that they were in this because they are concerned about public education, want to serve the local community, and want to make a difference, or that they simply enjoy teaching. As one PI observes, "It is more about people interest." We came across cases where faculty members had no idea how much they got paid for the involvement (because they do not care about it) or faculty who do not want course release because they "enjoy teaching so much."

However, most STEM participants acknowledged that both stipends and release time are attractive, and they naturally "appreciate the extra money." One PI observed that the idea of servicing the community appeals to the more established faculty, while the monetary incentive is more appealing to the younger, less established, non-tenure-track faculty. For community college faculty who have much heavier teaching load, stipends and release time seem to be more crucial. In general, faculty felt that their involvement was supported generously by the projects, although one PI noted that there is not enough support (money or release time) for faculty involved and "the good nature of faculty is always needed to make up for any insufficiency."

3.2.2 Providing Intrinsic Incentives

One department chair stressed the importance of combining "money talking" and enlightened self-interest when engaging faculty. It falls upon the project leadership to actively engage STEM faculty. A co-PI said, "The PI needed to beat down doors at the university to get more scientists involved. Energy is everything." Several pointed out the importance of finding STEM faculty with genuine interest in education who are willing to extend themselves rather than say "I have all the answers." One further noted that "it does take some hand-holding and reassurance." A project evaluator summarized that the key to engaging STEM faculty is to use time well, compensate them with money and opportunity to collaborate, and make them feel that their voices are heard. Otherwise, "they will vote with their feet."

In addition to providing summer stipends and course release, projects have employed a number of strategies to appeal to faculty's intrinsic motivations. While most projects recognized the importance of building partnership early on, many projects have a steep learning curve throughout the years about the values of providing professional development for STEM faculty and demonstrating sensitivity and flexibility to their needs.

Projects that made a substantial case for reform—that is, laid the intellectual groundwork early on for new roles and models of STEM faculty engagement with teachers—reaped the benefits as the project progressed. Project leadership is critical in establishing such groundwork. Meaningful and prolonged STEM faculty engagement hinged on two motivating conditions being balanced, or as one respondent put it, "the practical piece and the learning piece."

Professional Development

MSP has high expectations of STEM faculty engagement as an agent of change. However, obtaining a Ph.D. in a STEM discipline is often inadequate because the doctoral system is designed to produce researchers, not educators. One PI noted, "STEM faculty are typically clueless. They don't understand the content needs of K–12 teachers. They don't know where to start. And once they've gotten started, they don't know where to go."

Professional development for STEM faculty is an area of considerable growth over the years. Almost all case study projects are now providing some forms of professional development for their STEM faculty, even though some is less intentional and intensive than others. For example, the PD could be periodic (e.g., monthly) meetings or debriefings after workshops where faculty discuss among themselves and/or with other participants general issues pertaining to the project. Such issues have included course content, methods of presentation, texts, and program requirements or specific seminars about research, curriculum development, and assessment. Other projects provide more systematic and intensive faculty professional development.

- One project organized biweekly seminars involving participating STEM faculty, education faculty, and graduate students. In each seminar, participants discussed the books and literature they read about best practices regarding what courses need to be offered and how they should be taught for teacher preparation programs and inservice professional development. According to the PI, the biweekly seminar is the key to success in that participants forged common language, knowledge, and experience with each other. A senior STEM faculty said, "This is the methods class that I've never had before."
- Another project devoted an entire summer to providing professional development for STEM faculty members and teacher leaders on pedagogy and exemplary middle school curriculum materials before the teams were assigned to schools. Faculty contributed by assessing the curricula from the perspective of what kind of thinking is needed in college, addressing the problems that students have in moving from the concrete to the abstract and improving the scientific sophistication of lead teachers. They learned from teacher leaders about school contexts, student population, and state curriculum standards and assessments.

Seriously engaged faculty did not view their involvement traditionally in terms of outreach or service roles, but instead spoke of what they gained intellectually and professionally from participation. One project director reported that faculty "want professional development for themselves" because they "want to learn these things." Some examples of this intellectual engagement are as follows: frequent mentions of foundational MSP readings such as *How People Learn;* references to the IHE faculty professional development they experienced prior to working with teachers; long-term collaboration with K–12 science and mathematics teachers and teacher leaders; insights from the field of science and mathematics education research; participation in a lesson study or the examination of student work with an emphasis on student understanding; change in their own disciplinary teaching as a result of the MSP influence; discussions about student preconceptions, cognitive load, and questioning strategies; mention of a forthcoming publication in a STEM education journal; and presentations at a National Association of Research in Science Teaching meeting.

Building Partnerships

One of the major characteristics of MSP is the emphasis on partnerships. In the NSF model, partnership plays a critical role in the delivery of the program and in fostering a climate to support institutional change. The idea of partnership includes collaboration not only among institutions of higher education and local school districts, but also among the STEM faculty and other project participants. However, STEM faculty typically work in an independent fashion and may not be comfortable in a collaborative environment where people come from different backgrounds and have varying levels of content knowledge. Consequently, establishing and maintaining a true collaborative environment, especially setting up the framework, is critical to the project success as well as to STEM faculty engagement.

In six of the eight projects, STEM faculty work in teams with teacher leaders and/or education faculty, often in activities such as providing summer institutes for inservice teachers. Essentially, many of these projects were built on the "co-learner model," although STEM faculty roles vary from leading to supportive; in some cases projects specified the type of roles to be filled by participants, while in others it was left entirely for the team to figure out.

- For one project, collaboration among participants is inherent in its operational model known as Teacher Research Teams (TRT). The team is composed of college disciplinary and education faculty, high school teachers, and undergraduate and high school student tutors. The hypothesis is that teachers will improve teaching skills on the job in the presence of supportive instructional staff and strong content support while they provide summer camps for high school students who failed the state exams. A number of features are built into the system to encourage cooperation. For example, faculty and high school teachers spend a week working as a team to prepare curricula for the summer program. They deliver the instruction as a team. At the end of each day, each team spends one or two hours debriefing and reflecting about the day.

- The second project is decentralized in 10 school-based teams. Each team includes two IHE faculty, at least one of whom is a STEM faculty member. Other team members are teacher leaders, a principal, a guidance counselor, and school social worker. Working together as colleagues one to two days on average every month, IHE faculty and K–12 personnel tackle school-specific issues in STEM education and learning.

- The third project has a very unusual arrangement. During the three-week summer institutes, faculty and K–12 teachers are required to be in residence. This aspect of the program was credited with having created a bonding and a professional learning community that could not have been achieved through other means.

- Another project intended to bring faculty from all levels—grade school, middle school, high school, community college, and university—together by focusing on discipline dialogue on a particular mathematics or science concept. While most participants felt that they were able to connect informally with STEM faculty and developed some valuable relationships, the activity was discontinued because there were concerns that the episodic and "short-term" nature of the activity is not likely to influence teachers and students.

Generally, we have seen an increasing ease in communications between the STEM faculty and other members across projects over time. However, one PI pointed out that "willingness to work as a team is the toughest part." As will be discussed in Section 3.3.3, while many of the collaborators exhibit collegiality and camaraderie, in some instances the teams encountered problems at various points of the project. In a few cases, the PI had to switch teams so that people would get along.

Sensitivity and Flexibility to Faculty Needs

Projects are increasingly aware that they must be sensitive to the priorities and needs of STEM faculty. Perhaps the number one issue is time constraints. STEM faculty are often confronted by multiple and sometimes competing demands. For some projects, the fact that the majority of activities occurred in the summer may reflect projects' intentions that "research does not need to take a major hit," although some faculty view summer as the optimal time to do research. One project's experience is particularly illustrative. In the first year, STEM faculty expressed a concern about being stretched too thin by multiple responsibilities and time demands. Since then, the project changed the strategy by requiring intense STEM faculty involvement only in the year when their content area is featured in the summer institute.

Another need is to publish, and support and mentorship are important here. Trying to capitalize on the experience gained from the engagement in light of the need to publish, one project began to hold seminars introducing disciplinary journals open to pedagogical research and sharing experience about publications in pedagogy. Another offered a writing seminar that will give faculty an opportunity to chronicle their research findings and document the curricula they have developed.

One of the most involved STEM departments does not request recompense for its faculty's outreach involvement either during the year or in the summer. One reason is that the chair of this department became very involved with the project as a co-PI and has encouraged both his faculty and graduate and postdoctoral students to participate "because they are all either faculty or on their way to becoming faculty, and this is the only exposure they are likely to get to educational considerations." In addition, project participation is viewed as a *broader impacts* activity for faculty who have such obligations under current NSF grants. Similarly, faculty who intend to apply for NSF grants in the future will "have a head start on understanding what the broader impacts criterion is all about, so they are better able to craft that aspect of their proposals."

Flexibility is also an important consideration. One project has both mathematics and science components. While the science faculty are working with education faculty on the instructional team and seeking out increased variety of pedagogical strategies (e.g., sheltered instruction and differentiated learning) for both undergraduates and inservice teacher training, the mathematics faculty chose not to do so, as they felt that such arrangement would make it hard to recruit content-focused colleagues. "We are being tapped by the MSP for what we know—content, and not for what we don't know—school pedagogy," one faculty member told us. The difference between these two approaches appears to be a benign bifurcation.

After two years of engagement in summer professional development, lesson plans, and expert-in-residence activities, STEM faculty from one project were somewhat frustrated that they could not integrate their experience into their professional lives. The project redesigned its faculty involvement plan and left it up to faculty to choose how they wished to participate. As a result, some focused on pedagogy, some on content, and others on research. Only two faculty members stayed with the original concept of involvement. In general, STEM faculty took different roles in the schools because of different expertise, interests, and comfort levels.

3.2.3 Using Evidence-Based Evaluation

While supporting and engaging STEM faculty in MSP works is important, providing direction to better engage STEM faculty is equally crucial. One potential tool for improving STEM faculty engagement is evidenced-based evaluation, which can be an ongoing process to evaluate STEM faculty engagement itself and/or efforts to gather and use research and evaluation evidence to improve STEM faculty involvement. However, we found that evaluation is perhaps the weakest aspect for all projects.

Only one project surveyed IHE faculty with regard to their experience of the summer institutes. Another project added research components about higher education instructional/professional practice change using focus groups and observation in the second year of the project but did not pursue it after the project reprioritized its research and evaluation agenda. The use of evidence to guide the direction of STEM faculty involvement is also haphazard. We know that every project conducts evaluation, and we know that some have made such mid-course corrections in engaging STEM faculty as providing professional development. However, it is unclear from our case studies the extent to which evaluation evidence has been used in improving STEM faculty engagement, which is disappointing given the strong evidence-based emphasis in MSP projects.

One project designed an elaborate framework to assess STEM faculty engagement (Exhibit 3-1). Under the system, each faculty member's activities are tracked over time. Each type of activity is weighted by a numeric score. By the end of the year, the faculty member receives an annual score based on the average of activities. According to the project director, the system is a very useful tool as an internal resource, especially given the large number of STEM faculty involved in this project and the fact that it is coordinated through the university's outreach center rather than a STEM department or school. In a way, the system serves as a liaison between the administrators and STEM faculty. It allows the administrators to know the faculty and help them find their niche. In addition, it also helps the administrators to see participation patterns not only individually but also for the project as a whole. For example, the project quickly strengthened activities of community colleges once data from early years showed the lack of participation from community college partners. Data collected over time show that although the number faculty participating has dropped significantly from the 105 involved in the initial year—to 57 in year 2, 53 in year 3, and 42 in year 4—the depth of involvement (as measured by the faculty matrix, on a 1–5 rating scale) has increased in each of the subsequent years, from 3.4, 3.6, 3.8, and 4.2, respectively.

Exhibit 3-1. An example of measuring STEM faculty engagement

Activity	Level of point scale	Link to project strategies and objectives			
		Building future teacher pathways	Engaging K–12 students in high-quality MS curriculum	K–12 teacher and staff continual professional growth and development	Accountability for MS education
Keynote speaker or panelist, conduct lab tours	1	Undergraduate research assistants demonstrate lab activities to small student groups	▪ Introduction to STEM career pathways ▪ Enhances student participation		Enhancing mathematics and science concepts
Guest speaker project forums	2	Introduction to opportunities with faculty outreach collaborations			Recruiting quality MS teachers
Undergraduate research advisor	2	Exploration of scientific enterprise in math, science, engineering, and computer science			Promoting teaching as a career option
Judge competitions	2		▪ Enhances student participation ▪ Reinforcing student knowledge of research and presentations		▪ Creating challenging curriculum ▪ Encouraging students to think independently
University TEACH mentor	3	Applying research to the K–12 classroom			Recruiting and building quality MS teachers
Prepares and presents a several day course	3		Enhancing curriculum	Building content knowledge	Encouraging teachers to become intellectually engaged
Serves on faculty oversight committee	3				▪ Sharing models for outreach initiatives ▪ Providing recommendations to enhance student learning and professional development
Participation in discipline dialogues	4	Introducing teaching candidates to the elements of mathematics and science education	▪ Customizing student curriculum needs ▪ Linking to school curriculum	▪ Provide expertise in specific content areas ▪ Learning about K–12 students' education expectations and curricula development	▪ Restructuring curriculum to fit partner schools' needs ▪ Expanding faculty outreach collaborative to meet professional development objectives
Seminar course leader	4		Enhancing curriculum	▪ Providing teachers with university resources ▪ Building content knowledge	▪ Broadening information resources and network ▪ Encouraging teachers to become intellectually engaged

Exhibit 3-1. An example of measuring STEM faculty engagement—continued

Activity	Level of point scale	Link to project strategies and objectives			
		Building future teacher pathways	Engaging K–12 students in high-quality MS curriculum	K–12 teacher and staff continual professional growth and development	Accountability for MS education
Project director-design and implement student-direct outreach initiative	5	▪ Training graduate students to become undergraduate mentors ▪ Training STEM undergraduates to perform demonstrations at school sites ▪ Exposing undergraduate to leading and teaching a K–12 group	Performing presentations and demonstrations linked to the state standards	Introducing concepts and terminology prior to	Enhancing mathematics and science curriculum
Project director-design and implement teacher professional development and student direct outreach initiative	5	▪ Serves as an undergraduate mentor in a research facility ▪ Provides career-path guidance	▪ Demonstrating real-world applications to specific math and science concepts ▪ Students exposed to university environment through onsite hands-on lab activity ▪ Promoting a college-going culture	Demonstrating real-world mathematic and science applications that can be taken back to the classroom	Enhancing mathematics and science curriculum through exposure to broad applications
Project co-director—teacher professional development	5	Enhancing undergraduate curriculum	▪ Improving curriculum ▪ Linking MS curriculum to the state standards ▪ Enhancing student participation	▪ Providing teacher network ▪ Cultivating teacher leadership responsibilities	Improving math and science curriculum in partnership schools
Teaching SSMPP courses	5	▪ Building content knowledge ▪ Introducing teaching strategies		▪ Building content knowledge ▪ Introducing teaching strategies	Creating quality MS teachers
Principal investigator	5				Administering institutional change to the culture of PreK–6 math and science education

3.3 Operational Question Two: Has there been any change in the number of STEM faculty, extent and variety of involvement, and nature of collaboration between STEM faculty and other participants?

The extent of STEM faculty involvement in MSP has shown little change over time. With one exception, the scope of STEM faculty involvement established in the initial stage of the projects remained unchanged.

STEM faculty have participated in a variety of MSP activities such as teaching inservice teachers, working with K–12 and university students, curriculum development, project management, and research. The most common activities are conducting workshops with K–12 teachers that increase general content and/or pedagogical knowledge. However, the fastest growing area is research, particularly pedagogical research due to both top-down and bottom-up influences.

Case studies show that STEM faculty's working relationships with other participants such as education faculty, K–12 teachers, and teacher leaders are critical not only to making MSP a more positive experience for participants, but also to the success of MSP projects. Initial site visits found that the relationship between STEM and education faculty were collegial in some cases and problematic in others, depending as much on personalities as disciplines. Data in year 4 show that the relationships are improving over time. STEM faculty continue to enjoy a collegial relationship with teacher leaders. The quality of collaboration between STEM faculty and K–12 teachers has been generally rated high by both groups. A key to the success of these relationships is mutual respect and ongoing communication and dialogue.

This question was designed to explore the direct and immediate results of the project effort to support and engage STEM faculty by examining the level of engagement in terms of the number and extent of STEM faculty involvement, types of activities in which STEM faculty are participating, and the degree of collaboration between STEM faculty and other MSP participants.

3.3.1 Participating STEM Faculty and the Extent of Involvement

Data from previous years suggest that slightly over 1,000 STEM faculty participated in MSP activities. Although the latest count is not yet available, our case study shows that most projects are working with the same group of faculty. The number of STEM faculty involved in the eight case study projects varied considerably, from 8 to 50 with an average of 22 per project. Only one project experienced significant reduction from the initial year because one component of the project (i.e., disciplinary dialogues) that involved a substantial number of faculty was eliminated. Two other projects saw substantial increase of STEM faculty over time, but the increases were primarily due to the addition of new cohorts of teachers and programs, which is in accordance with the project plan.

While the MSP program assumes an increasing number of STEM participants over time, the reality is that the scope of STEM faculty involvement is fairly well established in the initial stage of the projects. The case study suggests that in some highly involved departments, STEM faculty participation is about 20 percent of the total disciplinary faculty. However, in many cases—especially for non-lead institutions—STEM faculty participation is often more of an individual choice rather than institutional effort. Many STEM faculty felt that few of their fellow faculty are interested in K–12 STEM education. One project director estimated that three-quarters of the faculty did not even know about its MSP, and its institute is generally "under the radar" within the school of Arts and Sciences.

Previous MIS data showed that 75 percent of the STEM faculty spent over 40 hours a year in MSP activities and 37 percent reported over 160 hours of engagement. In general, the extent of engagement is constant over time (Zhang et al., 2007). One case-study project had significant reduction of the number of STEM faculty involved but reported a greater extent of involvement for those remaining.

Participating STEM faculty came to the projects from different routes. The PIs from seven of the eight projects in the case studies are from STEM departments. They and a small group of STEM faculty members form a core group who initiated, designed, and actively participated in the projects. Recruitment strategies varied among projects.

- For three projects, recruitment is very selective and individual, as the leadership believes that the faculty engagement is not for everyone and should be by invitation only. One PI pointed out that "there are faculty and colleagues that I love and respect and have deep admiration for, but I wouldn't let anywhere near this project, because of the potential damage they could do." In general, the projects try as much as possible to invite senior faculty with friendly personalities, successful teaching experience at the college level, and some history of K–12 outreach.

- Other projects are more inclusive. One PI had to make presentations at the STEM departments in each college to attract the faculty. In at least two projects, the leadership were trying to attract mid-career or senior faculty who are no longer active in traditional STEM research. However, in both cases they found that these faculty members had also "checked out of scholarship entirely."

- Recruitment in one project has never been an issue because of the dual role of participating STEM faculty—engagement in science education is "part of their jobs." The only difference of the MSP project is that it allows them to work with inservice teachers in addition to preservice teachers.

- Only one project has an ongoing recruitment plan by providing opportunities for other faculty members to learn about participation in MSP through annual conference and colloquia, but they found that it is always the same faculty members who show up every time. However, the chair felt that there could be untapped potential applicants if budget is not an issue.

3.3.2 Types of Involvement

STEM faculty can participate in a variety of activities: teacher professional development, teacher preparation, teacher recruitment, curriculum alignment and revision, mentoring, and research. After addressing many misconceptions of scientists with regard to their involvement in K–12 reforms, Bower (2001) is optimistic that scientists can play a critical role even if their actual role is somewhat different from what they imagined it would be. Such roles include 1) program validation, i.e., the involvement of real scientists can lend essential political support for a project; 2) teacher support, i.e., the involvement of a scientist can have a profound effect on teacher optimism and emotional support; 3) resource acquisition, i.e., the current financial conditions of most public schools make the need for outside funding of reform project critical, and scientists can provide an extremely valuable service as grant writers and administrators; and 4) modeling the scientific process, i.e., STEM faculty skills in application of scientific investigation, critical thinking, imagination, intuition, and use of their hands are essential to scientific research, although they must be careful in the use of their content knowledge because it may be too specialized for the role they are being asked to fill.

The MSP program provides opportunities to investigate many of these theories and observations. In the past, we grouped the types of involvement by sectors—inservice, preservice, and project management—according to the MIS category. In order to better capture case study findings, we define the activities in terms of teaching inservice teachers, working with K–12 and university students, curriculum development, project management, and research. During the past four years, we found that the most common activities are conducting workshops with K–12 teachers that increase general content and/or pedagogical knowledge. However, the fastest growing area is research, particularly pedagogical research, due to both top-down and bottom-up influences.

Teaching of Inservice Teachers

The most common activity for STEM faculty is conducting workshops with K–12 teachers that increase general content and/or pedagogical knowledge. All of the case study projects involve STEM faculty in inservice professional development, and we found a variety of models for providing PD, with none of the eight projects identical in their approaches and strategies (Table 3-4).

- Providing PD for inservice teachers is the main focus for STEM faculty involvement in seven of the eight case study projects.
- With the exception of one of the eight projects, STEM faculty work in teams. They collaborate with teacher leaders in seven projects and with education faculty in five projects.
- Of seven projects involving team efforts, STEM faculty play a leading role in one, serve as equal peers in four, and function in a supportive role in two, acting as content resources for hands-on activities or laboratory sessions. However, at least for three projects, there seems to be a diminishing role for STEM faculty from providing direct instruction, as they tend to focus on research and observation in final years.
- Three projects view STEM faculty contributions primarily in terms of providing content, while STEM faculty are expected to be involved in both content and pedagogy in three other projects; for the remaining two projects, STEM faculty were expected to determine their roles to best complement the teams.

Table 3-4. Model of STEM faculty involvement in providing professional development for inservice teachers (case study projects)

Involvement	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
PD a major component		X	X	X	X	X	X	X
STEM faculty role								
Sole provider								X
Work with team	X	X	X	X	X	X	X	
Team composition								
Education faculty		X		X	X	X	X	
Teacher leaders	X	X	X	X	X	X	X	
STEM role in PD								
Leading			X					X
Equal		X			X	X	X	
Supporting	X			X				
Expectation of STEM contribution								
Content	X				X		X	
Content+ pedagogy		X	X					X
Determined by needs				X		X		
Degree of centralization of PD delivery								
Centralized	X	X	X		X	X	X	X
Decentralized				X				
Duration								
Summer	X	X	X	X	X	X	X	X
Year-long follow-ups	X	X	X	X	X	X	X	X
Grade level								
Grade/span specific	X	X		X	X	X		X
Mixed grade			X				X	
Cohort		X			X		X	
Involvement of K–12 students						X		
Graduate degrees/credits		X	X		X			X

C = Comprehensive, T = Targeted, I = Institute.

SOURCE: Case studies.

Other features are more related to the structure of PD rather than the particular involvement of STEM faculty.

- Seven projects provide PD for inservice teachers in centralized locations; one project has a tailored approach in providing PD to 10 different school districts in a decentralized manner. Specifically, the content of the PD as well as the timing of delivery are determined by teams of teachers, administrators, and STEM faculty, although the total amount of PD time is specified. However, the project added lesson plan workshops later and provided more structure where STEM faculty are co-facilitating the workshops and served in a more instructional role.

- PD is primarily delivered in the summer, but all projects include year-long follow-ups. These follow-ups can take many forms, including weekend seminars, lesson plans, expert lectures, and school visits or experts in residence. The extent of STEM faculty involvement in follow-ups varies greatly.
- The majority of the PDs are grade/span specific, but two projects provide PD to mixed grades/spans. The rationale for the grade/span-specific model is that teachers can immediately apply what they have learned to classes they will be teaching. The mixed grade/span approach is used so that teachers can see where their own instruction fits in the chain of knowledge and can provide a broader picture.
- Three of the seven projects adopted a cohort approach whereby they work with targeted cohort teachers for two years intensively. Other projects chose to work with one cohort of teachers but varied the subject or curriculum emphasis each year.
- One project offers PD as part of a master's degree program. However, PD participation in some other projects may count toward graduate credits. For example, teachers in one project can apply up to 20 credit hours from the project to a master's degree at the university through the School of Education (35 credits are needed for the degree).

Working With K–12 and University Students

By design, teaching preservice students is the primary responsibility for education faculty. However, for two case study projects, content courses for preservice students are traditionally taught by STEM faculty because of the state requirement, and content courses were taught in isolation without much communication with education faculty before the project. The MSP allows STEM faculty and education faculty to closely work together. For other projects, STEM faculty teach undergraduate content courses in which some students may become teachers.

Three projects also involved STEM faculty in preservice student recruitment and student mentoring. Only one project carried it out in a systematic manner. In fact, the major interactions for this project among the IHE sectors that are currently continuing are the two summer programs through a four-day summer residential program for community college students interested in K–12 teaching careers. One sequence for those interested in mathematics and science education at the elementary level and is open to all majors. A second sequence is for those who wish to become middle or high school mathematics or science teachers and is open to STEM majors only. The vision is to pool regional resources to recruit and support future teachers along the education continuum from K–12 to the community college and university levels.

Through workshops or daily interactions, STEM faculty actively encourage students to consider K–12 teaching careers. One math professor who developed a special track in his department for students to participate in a mathematics subject matter education preparation program that does not require a subject matter proficiency test to become credentialed reported that he "spends a good deal of my time recruiting students to be teachers." Another physics professor who developed the Physics Road Show, which is largely delivered by undergraduate students he has trained, identified those who "show potential of working with K–12 students and look like they are enjoying it" and encouraged them in this direction as well.

Although most MSP projects do not work with K–12 students directly, there are outreach activities designed to encourage the interest of such students in STEM disciplines. All of the Comprehensive and Targeted projects in the case studies have such elements (Table 3-5). For example, one project's outreach activities in the past year have included astronomy outreach (school visits, astronomy night, summer workshop), biological sciences (teacher programs, science fairs), chemistry (advanced placement at university lab, school visits), nuclear outreach course for grades 11 and 12, and physics assemblies. These outreach programs have included the participation of 42 STEM faculty, 60 graduate and postdoctoral students, 75 undergraduates, 478 K–12 teachers, and thousands of K–12 students. Depending on the weather, activities such as the physics assemblies (the "road show") and the astronomy nights can draw from 400 to 1,000 people, including parents. Specific types of outreach examples include the following:

- Middle and high school classes come to the university library's technology-aided classrooms and spend approximately two hours researching a given topic related to their current class work. They have access to databases and websites, and typically give oral reports on their findings. Following lunch, students participate in a secondary activity connected to their research—e.g., observing an undergraduate class on the topic or being introduced to special facilities at the university. Classroom activities conducted by their teachers at their schools both before and after the visit ensure that the component supports the students' regular classroom work.
- Science demonstrations are performed for elementary and middle school students at school assemblies. STEM faculty train and then accompany a team of undergraduate students to these presentations until they are certain that the assembly can be presented without their assistance. These activities are not regularly scheduled, but every attempt is made to have the topic coincide with what is being taught in the classroom.
- A Science Fair Initiative links research scientists, undergraduates, and teachers to create science fair programs at middle and high schools. Many components of these activities include Super Science Sundays, workshops at the schools, Ask a Scientist nights, visits to the university campus where the students work with undergraduate STEM majors on

their projects (the students commit to 10 Sundays for this activity), and other visits to observe college classes, attend Saturday morning Advanced Placement classes, visit the observatory or the nuclear research reactor, and participate in a standard four-hour laboratory period up to eight times a year.

Table 3-5. Model of STEM faculty involvement in working with students (case study projects)

Involvement	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Teach preservice/undergraduate content courses		X	X				NA	NA
Student recruitment and mentoring	X			X		X	NA	NA
K–12 student outreaches	X	X	X	X	X	X		

NA = not applicable, C = Comprehensive, T = Targeted, I = Institute.

SOURCE: case studies.

Course and Curriculum Development

All the projects providing inservice teacher PD involve STEM faculty in developing the training courses with K–12 teacher leaders and education faculty. Typically, the team meets one or two weeks before the summer institutes to design the courses. However, reforming IHE courses and curricula are more challenging, because they often involve changes in general university requirements, course titles, and listings in the university calendar; securing buy-in from STEM faculty who are not participating in MSP; and other political and administrative issues, especially if courses are open to students with other majors. These topics will be discussed in depth in Section 3.5.2. Projects' involvement in developing curriculum for inservice and preservice teachers is shown in Table 3-6.

Others are less structured and are based on individual initiatives. For example, a physics professor previously received summer hours to develop curricula and demonstrations (the Physics Road Show), and has now videotaped all of those demonstrations so they can be used if the schedules of those providing the demonstration do coincide with scheduled topics in a teacher's course. In another instance, a project paid for two summer months on two occasions and an entire quarter for a mathematics professor who has developed a special track in his department for students to participate in a mathematics subject matter education preparation program.

Table 3-6. Model of STEM faculty involvement in curriculum development (case study projects)

Involvement	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Inservice		X	X	X	X	X	X	X
Preservice		X	X					

C = Comprehensive, T = Targeted, I = Institute.

SOURCE: Case studies.

Project Management

STEM faculty had a considerable role in project management. Among the eight case study projects, the PIs of seven projects are STEM faculty (one project had a series of change in PIs). Other STEM faculty members also play a significant part. For example, one project has five committees. The STEM faculty are primarily involved in core planning, inservice professional development, and teacher preparation. They serve as "consultants" to K–12 curriculum alignment and assist in data collection for project evaluation.

Research

Perhaps the fastest growing area of faculty involvement is research, particularly pedagogical research. Up to the second year of this study, research was only identified as an area of STEM faculty activity in one of the eight case study projects. However, our latest round of visits found that five projects reported STEM faculty research (Table 3-7).

Table 3-7. STEM faculty involvement in project management and research (case study projects)

Involvement	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Project management		X	X	X	X	X	X	X
Research		X		X	X	X	X	

C = Comprehensive, T = Targeted, I = Institute.

SOURCE: Case studies.

The phenomenon might be explained by both top-down and bottom-up influences. The top-down influences may come from encouragement from the NSF MSP program or as a result of policy diffusion from venues such as MSP annual learning network conferences, MSPNet, etc. The bottom-up influences come from STEM faculty. For one project, STEM faculty acknowledged difficulties in transferring their project knowledge into their own professional lives and their feelings of being somewhat demoralized. Consequently, the project is trying to help channel faculty experience into scholarly research by bringing together STEM faculty, education faculty, and Ph.D. candidates in urban education. Interviews of STEM faculty revealed a few cases where the STEM faculty published articles on pedagogical research or wrote proposals on science education to NSF and other agencies.

3.3.3 STEM Faculty Collaboration With Other Participants

One of the key features of MSP is the emphasis on partnership. Although collaboration is easy to extol, it is difficult to achieve. Not only are there longstanding cultural differences between K–12 schools and IHEs, but the IHEs themselves are often characterized by a constellation of independent, disconnected principalities and fiefdoms. K–12 teachers can also be partnership-challenged. One of their issues is cognitive in nature, as the traditional professional development workshop model may be altered or even broken and alternative formats and relationships can be threatening. In addition, teachers work under serious time constraints. Partners also have to wrestle with status differences among faculty from different disciplines and between IHE faculty and K–12 teachers (Sussman, 1993).

Partnership in MSP entails formal institutional cooperation arrangements as well as interpersonal collaboration among participants. Our case studies show that STEM faculty's working relationships with other participants such as education faculty, K–12 teachers, and teacher leaders are critical not only to making MSP a more positive experience for participants, but also to the success of MSP projects. Initial site visits found that the relationship between STEM and education faculty were collegial in some cases and problematic in others, depending as much on personalities as disciplines. Data in year 4 show that the relationships are improving over time. STEM faculty continue to enjoy a collegial relationship with teacher leaders. The quality of collaboration between STEM faculty and K–12 teachers has been generally rated high by both groups. A key to the success of these relationships is mutual respect and ongoing communication and dialogue.

Education Faculty

The addition of STEM faculty to the education reform effort is one of the key differences promoted under the NSF MSP. Although there is a heavy emphasis on content knowledge throughout the

MSP, many believe it is not sufficient, especially given that many MSPs are promoting inquiry-based instructional practices. Consequently, education faculty play a critical role in many MSP projects.

Five case study projects involve STEM faculty working with education faculty. However, attempts to engage faculties in collaboration are sometimes hampered by a historical and persistent mistrust between the two groups, manifested by personality and pedagogical differences. Traditionally, STEM faculty tend to think that education faculty do not know the content, while education faculty think that STEM faculty do not know how to teach. Furthermore, education faculty are resentful because they feel they are not respected. Building on our characterization from last year (Zhang et al., 2007), case studies continue to demonstrate a variety of relationships from collegial to problematic, with the trend toward mutual understanding and respect.

- *The lucky ones.* Two projects reported no issues regarding faculty working together. They began with and continue to have relatively smooth relations. This particular scenario may have to do with multiple factors, including that faculty were purposefully selected and paired, and that they shared a summer professional development at the beginning of the project. It may also have to do with the supportive and non-leading roles that STEM faculty play on the team and the relatively small number of education faculty involved.

- *Benign bifurcation.* In one project, the science faculty are receptive to such instructional practices promoted by education faculty as sheltered learning and differentiated instruction. This is not true, however, for the mathematics faculty, as one described his course as "content-centric" and said that he was "highly skeptical of pedagogy." He believed that teachers were mostly interested in the content and not overly enthusiastic about learning "tricks." However, the differences over philosophy and practice have not been insurmountable.

- *Grow into it.* Cooperation between STEM and education faculty began on a relatively healthy note, although at times it involves campus politics and personality concerning "who's calling the shots and who's leading." However, everyone seems to agree that they have worked out the problems or at least have "agreed to disagree." STEM faculty said they used to have a "disdainful" attitude toward education faculty, but "as soon as we work with them, you come away with a whole different attitude," because they were impressed by education faculty's "good understanding of the content and a high level of professionalism."

- *Bumps along the road.* None of the projects working with education faculty have encountered widespread problems. However, there are instances where the differences were serious or irresolvable, resulting in the departure of some faculty from the projects. One project experienced a serious problem in year 1 in one of the teams. The problem was triggered by differences about pedagogical strategies, especially concerning the balance between lectures and activities, and the introduction of formal mathematics language into the discussions with the students. The STEM faculty member said the relationship was difficult because "we speak a different language," while the education faculty member thought that the STEM faculty member came in with an attitude of "let me show them what's going on." Both conceded that the disagreement "diminished the voice of the high school teachers." The STEM faculty member left the project. In another project, the incident occurred toward the end of the project. A math faculty member wanted to include discrete math at the summer institute, but the education faculty felt that it is too challenging for teachers. The math faculty member was unhappy about the lack of content focus and left the project. His departure was perceived as a major loss by several respondents as he was regarded as a prominent member of the team and a "teacher's teacher" by many K–12 teachers.

- *Do it alone.* For two projects, working with education faculty is not part of the project design. One of these projects is an Institute project. In the second project, all of the STEM faculty members involved have dual appointments with equal time devoted to disciplines and preservice teaching.

Reflecting on the relationship, one co-PI emphasizes the importance of valuing the integration of content and pedagogy and of having a long-term commitment. "The working together probably takes twice as long as an instructor than if I were to do it myself. However, over time, we're definitely seeing the benefits."

Teacher Leaders

In seven of the case study projects, STEM faculty work with teacher leaders who serve as intermediaries between university faculty and K–12 teachers. Some teacher leaders act as school liaisons; most serve as co-instructors in the summer institutes and play prominent roles in year-long follow-ups. Some teacher leaders are classroom teachers, while others are hired as full-time MSP staff.

- One project has identified about 100 teacher leaders. In general, a middle/high school has one teacher leader while an elementary school usually has multiple teacher leaders. School teacher leaders meet quarterly for half a day with university faculty to discuss teaching issues, peer coaching, etc. District teacher leaders meet once a month and are involved in the project's strategic planning. Teacher leaders observe, mentor, and motivate teachers; they act as liaison to the project and arrange school visits for faculty members. They also do demonstration lessons for peers, and some co-teach at summer institutes.

- Teacher leaders play a prominent role in another project. In addition to summer institute and year-round pedagogical rotation, full-time teacher leaders spent two days a week on sites observing classes and working with teachers on a one-to-one basis.

> According to teachers, the project staff (full-time teacher leaders) “always challenges us and asks us to think about our teaching; we have time to implement it in the summer and the work plan is hands-on and concrete.” Teachers mentioned that it is the most positive professional development they have ever had, because interactions were modeled and taught by themselves. In addition, teacher leaders provided Saturday workshops addressing teachers’ immediate needs, such as classroom management.

The relationship between STEM faculty and teacher leaders has become increasingly collegial. As one STEM faculty said, “We’ve become more than colleagues; we’ve become friends.” One PI observed that the successful collaboration occurred after participants had some association with each other. At the beginning of the project, it was a struggle for people to know what their roles were, and in a few cases, the PI switched teams so that people would get along. Many teacher leaders noted that only after some sort of an initial breakthrough did they become comfortable with faculty as collaborators and colleagues. These breakthroughs took the form of invitations (and following up on those invitations) to visit the campus to meet with them further and/or to bring their students there, staying after the official end of a seminar or workshop to talk with them informally, exchanging email addresses and telephone numbers, and agreeing to support other school activities such as science fairs, either themselves or by encouraging their graduate students to participate.

A key to this relationship is mutual respect. In one project, STEM faculty look to master teachers to help them assess the feasibility of things they want to do. There appears to be two-way learning that challenges the professional hierarchy in which professors may see themselves as superior to teachers. The same was observed by teacher leaders from another project: “Learning is a two-way street in these relationships. When a faculty member says that he or she has learned something from or with me, that is a true collaboration.” In fact, teacher leaders commented, “It was fun to watch STEM faculty including the PI struggle with inquiry teaching when they modeled it and tried it out.”

Teacher leaders felt that professors treat them as colleagues and professionals, especially when they respond to the teachers’ emails and calls with questions. Several have taken up the invitation to bring students to campus to visit labs. STEM faculty are very careful about letting teachers have their say. Other teachers mentioned that an additional quality that defines a good partnership is a continuous commitment by faculty, “not just a one-time visit.” The ongoing, personal relationships that were developed between teachers and STEM faculty were cited by the teachers as the primary reason why MSP was preferred to other forms of professional development.

There are also issues with relationships. The small ones often include scheduling, because everyone has too little time. In addition, teachers sometimes have difficulty in determining which faculty member to ask a specific question. Other issues are larger. Even if some projects are based on a co-learner model, some teacher leaders complained that the STEM/teacher interaction is still "here is how it is" and "this is right and this is wrong," with STEM faculty resistant to entering into a process with the teachers. Faculty also noticed cultural differences as they found teachers being uncomfortable with what faculty viewed as "constructive criticism." Teachers sometimes felt that their professional knowledge was being challenged. One STEM faculty remarked, "There is a fine line between being useful and threatening. You always have to be willing to back off with teachers."

One project experienced problems in faculty-teacher leader relations in the first year. The teachers did not feel they were being treated as peers because of the hierarchical university structure. By the second visit, the situation appeared to have eased through self-reflection from the project leadership and careful selection and hiring of a new class of six teachers from the ranks of project-related teacher teams. Teacher leaders were not given any formal teaching or large group discussion leadership roles in the daily classes but felt included in the life of the partnership. During the last two visits, we found that teachers taught in classes on pedagogical strategies and led whole group discussions. They described the relationship with STEM faculty as "fantastic" and "the highlight" of the MSP experience, stressing that both faculty and teachers were "in the same boat" trying out new methods of teaching and learning as "compatriots." Faculty began to appreciate that they had a dependable teacher contact and reliable project resource. The nature of collaboration has undergone a salient shift since the first visit.

K–12 Teachers

In most cases, STEM faculty members interact with teachers through the summer institutes. The relationship between STEM faculty and the K–12 teachers was rated as positive overall by both groups. According to the teachers, the professors are receptive to their needs. In fact, many teachers had feelings of trepidation about working with STEM faculty at universities and expected to have more difficulties communicating with such people of "exceptional intelligence." However, they were pleasantly surprised at the ease with which the professors could relate to them and their concerns as K–12 teachers. STEM faculty may also be apprehensive because they are unfamiliar with working with teachers and are unsure how to approach them. This mutual fear may turn into mutual respect over time.

In other cases, teachers may initially feel that they have to prove themselves but the attitude quickly diminishes because of an absence of status issues. In the project with a residential summer institute, the faculty were there to assist teachers not only in classes and study hall, but also in the dorms where teachers were doing their homework. One teacher remarked, "When do you get an opportunity to play kick ball with the IHE faculty and then sit down the next day to talk about combinatorics?"

One PI observed a mutual respect: "Teachers trust them (faculty), and they like being around each other." One teacher said, "We found that they are just like us. We enjoy getting to know them as people." Teachers noted that while the professors they had in college tended to show "one way" to solve problems, here they got to explore "more choices." They found STEM faculty to be open, accepting, accommodating, knowledgeable, respectful, and approachable.

Another PI maintained that the key to engaging STEM faculty has been to involve them on school-based teams, which enables them to bond with teachers and learn about school culture. They had to "get their hands dirty." However, for most projects, the collaboration primarily is limited to the summer months—a more traditional schedule for working on activities outside STEM faculty academic duties. The seminars offered during the year are often limited to one to two days, and teachers are more likely to interact with education faculty and project staff than with STEM faculty.

3.4 Operational Question Three: What are the effects of STEM faculty engagement on teachers, students, and STEM faculty themselves?

Initially, many STEM faculty expected to see positive impacts on teacher content knowledge. As the projects mature, there is an increasing realization among faculty that pedagogical skill is at least as important as content knowledge for K–12 teachers. Throughout the past four years, teachers reported learning both content and, especially, pedagogy and increasing confidence. However, caution is necessary when interpreting the self-reported data, as observations of teacher instruction suggest that the real changes in instructional practices are not as great as those self-reported. In addition, STEM faculty involvement is rarely seen as the sole or even the main contributor to the changes reported.

Respondents continue to be less certain about direct impact on student achievement from the very beginning. Many hope that the effect on teachers will filter down to students.

Despite concern about state assessments and attribution, many are anxious to use state assessment results to validate project success. However, even though there is evidence showing that student achievement is increasing toward the end of the projects, few are comfortable with attributing the progress to STEM faculty involvement either because STEM faculty are primarily working with teachers and not students, or because of many other confounding variables. Most respondents pointed out that other types of student impact, such as student attitudes and the ability to think and understand deeply, are equally important.

Perhaps the biggest surprise is that participating STEM faculty increasingly acknowledged learning on their part from the MSP experience in terms of becoming better teachers themselves, understanding K–12 perspectives, being exposed to teamwork and connections, and undertaking new research activities. A STEM faculty teaching style that is more active, collaborative, and student-centered is one of the unintended consequences of the MSP activity.

Despite the considerable literature on partnerships involving STEM faculty, research on the impacts of STEM faculty involvement is limited. Many studies have suggested a variety of benefits from engaging STEM faculty, but the suggestions have been based more in theory or anecdotal reports than on empirical evidence. Our study is designed to directly examine the process and impacts of such engagement on K–12 teachers, K–12 students, preservice students, and STEM faculty themselves.

However, in making statement about impacts, one must consider several caveats. For purists, causal claims can only be made based on results from experimental design involving random assignment, while others are often too willing to assign "causality." For this project, we acknowledge the difficulties and are explicit about the caveat concerning impact statements about STEM faculty involvement. First and foremost, the study is primarily based on observational data, which lack counterfactuals. Therefore, we have a nonexperimental situation in which the comparison is based on different levels of STEM faculty involvement across projects or over time. In addition, as discussed before, STEM faculty operate in a team environment, making it difficult to tease out their individual contributions. A compromise is to make logical arguments to enhance empirical evidence: if a project has an impact, and if STEM faculty play a significant role in the project, then they may have contributed to the observed effect.

We gathered some preliminary evidence from site visits on the perceived impacts from different respondents. A summary of the areas examined in the case study projects is presented in Table 3-8.

Table 3-8. Perceived outcomes of STEM faculty involvement on teachers, students, and faculty (case study projects)

Outcome	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
Improvement of K–12 teachers								
Content knowledge	X	X	X	X	X	X	X	X
Pedagogical skills	X	X	X	X	X	X	X	X
Confidence	X	X					X	X
Improvement of K–12 students								
Achievement		NV	X	NV	NV	X	NV	NV
Engagement	X	NV		NV	NV		NV	NV
Improvement of STEM faculty								
Understanding of K–12 perspectives	X	X	X	X	X	X	X	X
Pedagogical skills	X	X	X	X	X	X	X	
Collaboration	X	X		X	X	X		
Research			X	X	X	X	X	

NV = not available, C = Comprehensive, T = Targeted, I = Institute.

SOURCE: Case studies.

3.4.1 Changes in K–12 Teachers

Some literature suggests that IHE faculty involvement in teacher professional development can have a positive impact on teacher quality, while other works point out a number of challenges for STEM faculty in working with K–12 teachers. For example, the specialized knowledge of STEM faculty may not necessarily benefit teachers and teachers may be inclined to disregard the advice of faculty, believing that their recommendations will not be useful because they lack experience in K–12 classrooms. In addition, STEM faculty often lecture, which may reinforce traditional methods of teaching (Wallace and Kang, 2004). Our preliminary findings suggest that STEM faculty involvement has a positive effect on teachers in areas of content, pedagogy, and confidence. However, STEM faculty involvement is rarely seen to be the sole or even the main contributor to the changes observed. There are disagreements on the relative strength of impacts among different respondents.

Content

For many, the dichotomy between content and pedagogy is artificial and moot. Teachers often told us, "You can't have one without the other," and "I've learned a lot of content but there is so much pedagogy wrapped up in content." Many teachers viewed STEM faculty as providers of content. They appreciated the depth and breadth of knowledge that STEM faculty offered and saw that knowledge as more extensive than what they normally received from other professional development providers. Overall, participants noted the content focus of MSP. One teacher pointed out, "This is the first professional development I have had about content." They acknowledged that STEM faculty brought different levels of understanding and maturity to the content. They helped teachers break things down. Teachers also liked the ongoing nature of the engagement and emphasis on problem-solving and thought process, as well as that the professional development is based on research of what works.

However, it appears that teachers' gain in content knowledge depends on several factors. Not surprisingly, teachers are more likely to report gains in content from projects that emphasize content. In general, teachers appreciated that STEM faculty had "high standards for content and the content knowledge is geared towards educators and at a right level." Two projects administered pre-post tests of teacher content knowledge before and after the summer institutes and a delayed assessment one year after the institute. Results show improvement in teacher content knowledge, providing evidence to support that at least within the narrow content area presented at the summer institute, participating teachers demonstrated knowledge gains. Teachers in other projects also acknowledge increase in their content knowledge. "The program kicked my butt, but it was well worth it," said one teacher.

The second factor regards the utility of the content knowledge. Many teachers value what can be directly applied to the classroom, while others want the broad pictures and issues. It seems that more teachers may fall into the first category, even though STEM faculty generally are more effective in the latter. To illustrate the point, we found that teachers were often less concerned about content. What they needed was how to get the content across. In fact, they sometimes felt that STEM contributions were too content-driven, and what is needed is "content in context." One teacher mentioned, "The level of content detail that STEM faculty insisted on was too much for the students and prevented teachers from finishing the curriculum. We need to be able to see the bigger picture."

For one project, STEM faculty are specifically involved in providing the "challenge of the day," designed to put teachers out of their comfort zone, during the summer. Some teachers admitted that they were initially uncomfortable and felt that their intelligence was questioned. But in the end, they learned how to think from the exercise. A district specialist observed that at the beginning teachers freeze up, but going through it, they realize that there is more than one way of thinking. The district specialist pointed out that now many teachers start their classes with a "problem of the day," and the instruction has become less textbook-bound.

In many ways, gains in content also vary from teacher to teacher and by grade level. Teachers with content backgrounds stressed new ways of presenting materials and guiding discussions, while those without content backgrounds, most often the elementary schools teachers, emphasized the content gain as well as new teaching strategies.

At the beginning, most STEM faculty members were insistent that teachers would learn content more than pedagogy. One said that teachers "have to have this" and need to take courses beyond what they teach, and STEM faculty are in a unique position to help teachers to see beyond the range of K–12 mathematics. Some STEM faculty members were skeptical of the pedagogical strategies advocated by the project. As they became more involved in the projects, they admitted that adjustments needed to be made in courses and expectations at least early on because of the range of skills and knowledge among teachers. Additionally, there is an increasingly realization among STEM faculty that pedagogical skill is at least as important as content knowledge for K–12 teachers.

Although the project is built on a collaborative learning model, some STEM faculty came to the project wanting to "model excellent teaching." One faculty member reflected in retrospect,

> We were way too naïve. We thought we could take content experts and mix them with high school teachers. Teachers would suck up the content that STEM faculty would provide with innovative pedagogy. Well, it works only when you have a perfect faculty—which is rare. What we found is that a typical STEM faculty is not comfortable with high school teaching.

The PD noted that content knowledge and the knowledge needed to teach the content are two different things. Also, the additional content that was inserted for the benefit of the teachers was often too demanding and prevented them from finishing the curriculum.

Pedagogy

Our case study data suggest that MSP puts a premium on STEM faculty's contribution to content, but many teachers tend to emphasize gains in pedagogy for mathematics and science from the project. This may be a function of how the content is delivered. Although not part of an MSP requirement, the majority of projects are employing the National Council of Teachers in Mathematics (NCTM)-endorsed approach that links content to constructivist pedagogical practices.

In addition, as we showed in the previous example, some K–12 teachers and principals maintained that "content is not the problem, but how to get the content across to students," suggesting that what is needed is content in context of their instructional needs. Where professional development is not grade-specific, teachers may also be more likely to see benefits in pedagogy rather than content, as the latter is generally less transferable to classrooms. Because STEM faculty are not primarily charged with reforming teacher pedagogy, it is unclear how much of the pedagogical benefit can be attributed to STEM faculty.

- In one project, teachers have embraced, to various extents, the highly constructivist pedagogy involving small-group interaction, manipulatives, and hands-on activities. Some became great proponents. One teacher told the site visitors, "I was in a rut…they made us go (to the project PD) but I found it to be a wonderful and different experience with a lot of manipulative, research and games. I got on." The teacher was a participant in the first year and became a presenter later. Generally, the idea of teaching in depth and conceptually is new to many teachers, but once it is modeled by the project in the summer, they really like it. The challenge is the time it takes to integrate them. A more fundamental impact is to realize that math is not just paper and pencil and "doing math," but rather thinking math in different ways. Teachers are appreciative of the research-based pedagogical lessons and resources provided by the project, which make them feel like "professionals."

- Respondents in another project universally felt that there had been a change in teacher practices, and some perceived that these changes were spreading from the project participants to others in their schools. The acknowledged changes include moving from the individual mode of planning and teaching to a more open collaborative mode, moving from a focus on what the teacher is delivering to how students are receiving the information and how they are thinking about it, recognizing that there is more than one way to solve a problem, and using justification and generalization. One STEM faculty added, "K–12 teachers have a tendency to try to make sure things are as simple as possible to be easily understood. IHE faculty believe that being stuck is okay. STEM faculty like to work through problems and now teachers feel it is okay to put kids into disequilibrium."

- The third project conducted classroom observation on selected teachers twice a year using Horizon's observation protocol. The evaluators felt that growth in pedagogical knowledge and delivery strategies is attributable to the common framework of *How People Learn*. The PI said, "We buy this book and use it. Everybody was given a copy."

- In the fourth project, teachers unanimously credited the project for their pedagogical gains. One principal noted that teachers were skeptical in the first year. After they participated in the summer activities, they became promoters of the MSP. "They don't see it as a program, but a way of teaching." However, it is unclear how much of the gain can be credited to STEM faculty participation. When asked from whom they learned the most, teachers tend to mention the names of the project staff (full-time teacher leaders) and non-STEM faculty members. Furthermore, teachers have difficulties translating their summer experience with its controlled environment and the personal instruction that they receive to their everyday classrooms.

The site visitors across projects observed many elementary and middle school classes taught by MSP participants. They frequently saw that teachers divided the class time into lectures, group activities, different levels of questioning, and peer grading. Teachers appeared to be comfortable in delivering the content and having students take more responsibilities. Teachers were asking "why" questions, probing student reasoning processes, and using new techniques and manipulatives, and examples of effective incorporation of exercises, graphing, and independent problem solving were abundant. Many of the teachers are veterans and have served either as district or school teacher leaders for the projects. We are also mindful that the teachers we observed are more likely to represent "best practice models," that is, master teachers, rather than the norm.

Indeed, the majority of the classes were well-taught with some common features: 1) the instruction was more student centered than teacher directed; 2) students were organized in small groups; 3) there was considerable student participation with strong emphasis on participants articulating their thought process; 4) most classes had hands-on investigation activities involving packets and sometimes even home-made materials that enable students to replicate experiments outside the classroom; and 5) there was a focus on real-life application with problems. The extent of technology use varies by project and teacher.

Exhibits 3-2, 3-3, and 3-4 describe classes we observed that represent a varying quality of implementation. The first example (Exhibit 3-2) is an ideal case in that the instructor incorporated essentially every best practice and instructional technique to produce a highly engaging session.

Exhibit 3-2. Observation summary of a grade 7 science classroom

Classroom characteristics	Lesson summary	Interview summary
Grade: 7 **Students:** 24 **Setting:** Science laboratory/ classroom: Modified block schedule **Topic:** Carbohydrate tests **Observation Time:** 90 minutes	**Specific STEM content:** Carbohydrate Tests (Text: MS Life Science, Kendall Hunt.) Students guessed at whether the sugar content was high in different foods and then tested each. The teacher did not expect to be observed this day. He was informed one hour prior to our arrival. He had no problem with the short notice. He was a very skilled instructor and the students were engaged in the lesson. He had an excellent rapport with seventh graders, many of whom were "impacted students" in need of extra help. An aide assisted. The lesson began with a warm-up exercise about foods that contain sugar followed by a review of predictions using a chart. Next, the teacher engaged students in a lab to test samples for sugar using Benedict's solution. After making predictions and recording them on data tables, students worked in pairs at lab tables. They were very focused and interested in their findings. The teacher circulated among them praising their efforts. After an hour of lab work, students came together for the teacher to demonstrate his corn syrup density tube. Next, they filled in the master data table with their lab findings. In closing, the teacher said that tomorrow they would tie together the data. The teacher employed essentially every best practice and instructional technique. The class seemed well organized and the students seemed engaged. It was a laboratory exercise and, by default, was problem based and hand-on.	**Years Teaching:** 7 The teacher had taught five years in middle school and two in elementary school. He had a bachelor's degree in geology and a master's in middle school science. He has taken six MSP courses. He had never had a negative experience with STEM faculty and was very positive about the impact the project has had on him. He found the faculty open, accepting, accommodating, knowledgeable, and approachable. He likes the model of content experts with teachers. He started out taking the classes for the stipend and credits, and then really liked them. He especially loved the dinosaur dig. Overall, the instructor had a very satisfactory experience with the program.

However, we are frequently told that it is hard to change pedagogy and teachers do not become "effective" overnight. The following is another case in which the teacher was enthusiastic and incorporated many elements from MSP in her class, even though there are areas that need to be improved (Exhibit 3-3).

Exhibit 3-3. Observation summary of a grade 8 mathematics classroom

Classroom characteristics	Lesson summary	Interview summary
Grade: 8 **Students:** 26 **Setting:** Regular classroom **Topic:** Linear equations **Observation Time:** 95 minutes	**Specific STEM content:** The lesson was about using specific strategies, e.g., the "Basket of Strategies," to solve linear equations. The strategies emphasized were to make graphs, construct tables, and use equations. Members of student teams worked problems on the board after solving them as a team. Ninety percent of the class are honors students. The class was a warm-up for a test. The students worked problems in groups and then volunteered to go up and show their work. There were a couple of technical errors, but they were minor and not likely to create misunderstandings. The teacher used an overhead projector to display equations. She demonstrated how to use strategies to solve them. After working with the warm-up questions, volunteers worked problems on the board. Students used a calculator to *check* their work, not to solve the problem. After one set of board problems was solved, the teacher had a discussion of rounding and repeated decimals and precision vs. estimation. In one example, she mentioned the advantages of using improper fractions in solving a particular problem. Following another problem, there was a homework review. Before a brief partner quiz, the students solved a problem about a parachute that was caught in a tree. The text was "Connected Math 2." They also used a booklet, "Thinking with Mathematical Models—Linear and Inverse Relationships." The teacher was very positive throughout the lesson and interview, and the students were engaged in the lesson. The teacher encouraged students: "Show your thinking as a partnership in your group." "There has to be reasoning behind your thinking." The Socratic questioning method was used, and students seemed comfortable with it. Students were engaged and the instructor was enthusiastic.	**Years Teaching: 8** Taught grades 7–8 for four years and K–5 for four years. Has taken 21 MSP credits. Wants to be a teacher leader in the future. Involvement in the project was "life changing." The modeling vs. direct instruction was great, and it encouraged her to make the effort to get a master's degree. The money provided by MSP made it possible to pursue the advanced degree. She said that she was always good at math facts, but now she "knows it deeply." She has recruited one teacher into the program, and she is working on another. When asked what she had learned since the beginning of the project, the teacher said, "I didn't know what I didn't know in the beginning." Nothing is the same with her teaching and she has great confidence now in what she's doing. Her students' achievement scores have increased; 18 of her 32 lowest scoring students in another class had more than one year of math growth. They seem more willing to share and explain their thinking.

In the last example (Exhibit 3-4), the teacher appears to have all the right credentials and to speak the right language in interviews. However, the lesson we observed was not satisfactory.

Exhibit 3-4. Observation summary of a grade 5 classroom

Classroom characteristics	Lesson summary	Interview summary
Grade: 5 **Students:** 18 **Setting:** Regular classroom **Topic:** Box and T-chart **Observation Time:** 60 minutes	**Specific STEM content:** Mean, median, mode, etc. (continuation of previous lessons). "How many drops of water fit on a penny?" Material was presented rather clearly. There was some encouragement to generate ideas and questions. Science journals were in evidence and a box and T-chart were discussed. The box was for emphasizing *similarities* and the two columns of the T-chart were for listing *differences*. The teacher opened by telling the students to avoid words like "stuff" in their journal writing. Students worked in groups in six teams and were scheduled to report out with a chart displaying results. The groups appeared to be working with the "drops per penny" data of teams different from their own. There was off-task talking in one-third of the groups and confusion as to the assignment. One group acted out consistently. The class was not very effective. Teacher: "I need you looking up here. What is the median? What is the median for 20, 20, 17, 18, 17, and 19?" Discussion as to why 18.5 was the median. The mean was next for this set of numbers. Calculators were handed out to add the numbers and divide the total by 6. Teacher: "Why would you want to calculate the mean, median, and mode for these numbers?" One hand up—Student: "Shopping. You don't want to bring too little money." Students were not engaged. The teacher's attitude seemed downbeat at times: "Some ideas are not as important as other ideas." The lesson appeared prescriptive rather than engaging: "Write this down." "We have been working on this for a LONG time." Not much evidence of MSP principles in this lesson on this day.	**Years Teaching: 21** Teacher has a strong science background with advanced degree in science. Teacher served as a teacher leader last year. Said that she is having a hard time adjusting to coming back to the classroom. The teacher told us that the lesson prepares students for understanding variables. She worried that the "kids are not bothered that you get different results." The teacher was clearly exasperated. "These students," she said in a later interview, "were very difficult." The teacher admitted that lesson was too much "Me tell—you do."

Although many of the lessons observed were successful, we came away with mixed impressions of how the projects are affecting actual practice. Despite overwhelming testimony about gain in instructional practices from self-report, the transfer of project-gained knowledge into K–12 classroom is not a certainty.

Confidence

Many teachers regard MSP involvement as life changing, "Nothing is the same with my teaching." Greater content knowledge and pedagogical skill often translate into higher confidence. In addition, teachers are thrilled that STEM faculty are involved because it shows what they are doing is valued. "It is motivational and you get a sense of being respected."

Teacher confidence is another area in which gains were consistently reported. One teacher noted, "I felt so much more comfortable about opening up the floor for students to ask questions. I didn't feel like my lessons had to be as closed and scripted because I felt I could probably answer them. And if I couldn't, I had somebody to call who could help me answer them too." A related sentiment is that "the association with STEM professors makes us (teachers) look better and feel better." More importantly, teachers added that STEM faculty can validate their correct solutions when they need to find arbitration so that they are not afraid to take on math arguments. Teachers derived a sense of self-respect and the feeling of being professional. Another source of confidence comes from connections with like-minded teachers from other schools, which is especially important for teachers from small schools. In some cases, teachers are also becoming more aware of cross-disciplinary connections, being more open to constructive criticism from peers, and are more confident and motivated.

As a result, participants are more motivated and are willing to take lead roles in schools. Many teachers put on sessions for other teachers in their schools that are often based on topics and concepts covered at the institute. For many projects, participants are expected to become leaders in their districts who can help others learn the principles and approaches taught during the summer. One content specialist noted that as a result of increasing confidence, teachers are more willing to speak up at district-level meetings. In addition, one master teacher indicated that as a result of his MSP involvement, for the first time procedures have been put in place to allow teachers to explore a new career track as adjunct faculty at the participating universities while maintaining their status as school district employees.

To a large extent, the main focus has been on leadership, with strengthening content knowledge being seen as a tool for making teachers better leaders. However, we also heard of instances where this role was enacted in the face of lack of support (not necessarily active interference but rather passive behavior) on the part of principals and district leadership.

3.4.2 Changes in K–12 Students

Although most STEM faculty do not work with K–12 students directly, the expectation is that the effect will filter through teachers. In previous years, respondents expressed a spectrum of views about a direct impact of STEM faculty involvement on student achievement. Regardless of the perceptions, all respondents were anxious to look at student performance as validation of project success, an attitude that continues to be true this year.

There is some evidence showing that student achievement is going up—that is, a higher percentage of students are meeting the standards now than previously. However, few K–12 respondents are comfortable with attributing the progress to STEM faculty involvement, and STEM faculty are even more cautious to do so. On one hand, people are very frustrated about a lack of evidence on student achievement. "I would like to prove something—that it is really having an effect," notes one project leader. On the other hand, a project evaluator commented, "I don't think we are ever going to be in the position to do that." The inability to make attribution has to do with both project design and evaluation methodologies. STEM faculty are primarily working with teachers and not directly with students. Even if there is an effect, the primary impact is on improving teacher quality, and student achievement should be a secondary effect. In other words, STEM faculty are "two orders removed from students." In addition, there are too many confounding variables in attributing the observed improvement to STEM faculty participation.

- STEM faculty are often part of the team. It is difficult to tease out individual contributions from the mix. Only one case study project works directly with students who had previously failed the state exam. The impact on these students was obvious, with passing rates between 75 and 90 percent after the summer. During the summer, students worked with the team and took an exam every week. A teacher observed, "Their motivation went up. They took pride in seeing the results, even though they may be sick of their tutors. There was a change in their mindset and they came to believe that college is a real possibility for them." However, the PI was baffled about where the credit should go. "We saw passing rates going up, but it is not because of STEM faculty, nor do I believe it is due to high quality of teaching—because it is not…Kids love to be on a college campus and with college professors, but it is not clear whether they have an impact." For the majority of students who were not directly involved in the intensive summer program, the impacts are likely to come through their teachers. However, the model also requires significant resources, and it is difficult to replicate the success in schools where students do not get one-to-one attention. The schools are exploring different ways of using college and high school tutors.

- Some are not sure that student impacts would be manifest on high-stakes tests, which may not assess understanding. The emphasis on memorization of facts on the state

> assessment is not aligned with the project emphasis on understanding of concepts because teachers will be busy "ensuring that their students know the required facts and do not have opportunities to delve deeper into important scientific concepts." One principal pointed out, "One of the down sides of the project is that they are still using the statewide assessment, which does not measure deep thinking. We are a Title I school and over 90 percent students are meeting standards. We can't show an MSP effect."

Other student impacts are more subtle. For example, most teachers from one project recognized improved math discourse in their classes and attributed the improvement to their MSP experience. Some felt strongly that there were signs that students were making progress: "Students are coming to the next grade with greater sense of what it means to 'talk math' and can communicate their thinking more." Students are more willing to share and explain their thinking.

In another example, the district specialist noted that the main impact is student ability to understand and think more deeply. In the long run, it will translate into achievement. Teachers also observed some changes in student attitude in terms of more confidence in thinking on their own and volunteering in classes. One student told the teacher, "It is not like being in a math class." The principal also noted more student engagement and interaction because math is no longer just "lecture with workbook." Students are talking and writing about math now—"It never happened before."

Increased K–12 student motivation and more favorable attitudes toward math and science were attributed to project participation by every teacher interviewed throughout the four years of site visits for one project. Day at College not only incorporates a visit to a university campus, it also is crafted to meet state content standards. As one teacher said, "The students are having fun and learning—and we are actually doing what the state requires!" Another said that "the hands-on experience in a college setting is very inspirational to the students." In the survey after each session, most students (87 percent) reported that they had learned new ideas, and more than three-fourths reported learning new skills.

3.4.3 Changes in STEM Faculty

MSP views STEM faculty as a change agent whose involvement will benefit teachers and students. However, one of the major findings is that STEM faculty members derive considerable benefits from their engagement. The fact that many of the same faculty have worked with the MSP projects from the beginning reflects their continuing interest and motivation and, most likely, a mutually beneficial relationship. We often hear STEM faculty use words such as "most rewarding," "positive," "invigorating," and "eye opener" to describe their project experience. Faculty members from six of the case study projects citied benefits for their own instruction in that the experience made them think about content, exposed them to pedagogy, and to varying degrees, changed their pedagogy.

The major impact is that MSP makes them better teachers. A major personal "aha" was the discovery of active teaching strategies, which has reshaped faculty members' ideas about learning. Many STEM faculty noted that they received no training in pedagogical methods during graduate school and had to learn on the job. The types of changes STEM faculty have made in their own university courses include using more questioning, working with groups, making connections with prior knowledge, introducing concepts in context, and teaching for diversity—it is more of a constructive, inquiry-based and hands-on approach than the lecturing approaches they had used in the past. For others, such strategies were an extension of what they were already doing purposefully or intuitively.

- One science faculty member has altered the introduction to environmental engineering course. Instead of lecturing, she is having students conduct case studies of real-world situations such as examining the pollutants produced by a chicken facility. Another added, "I now take more care in explaining the concepts and make sure that the very basic things are understood." He is also designing his course backward by starting with the learning goals and thinking about activities, and building strategies to realize the goals with more real-life examples.

- Exposure to team teaching was an eye-opener for faculty from another project who usually taught independently and, at most, collaborated occasionally with another professor. Now they began working with faculty not only from the same departments but also from other disciplines.

- In one project, faculty unanimously agree that the biggest surprise is how much STEM faculty can learn from teachers. In the first year, they realized how much lecturing has been going on in their own classrooms and now there is a general acknowledgment of pedagogical content knowledge—what you know is different from knowing how to teaching the content. The experience also forced faculty to reflect on their own teaching and even content knowledge. One acknowledged, "By doing something for a long period of time, you tend not to think about how you're doing it or how well you are doing it."

- Faculty from a prestigious university had difficulty citing specific ways they benefit from MSP. However, some noted that working with an entirely different set of nontraditional students led them to reflect on their teaching in general and allow them to think deeply about science.

A second major impact on faculty is the knowledge of K–12 schools and challenges faced by the teachers. Overall, STEM faculty in all eight projects agreed that the experience helped them think about education and its goals on a broader basis, not just at the university level. As a result of MSP, faculty have more appreciation for what teachers have to do at K–12 schools and, in some cases, they even learn about K–12 practices.

- STEM faculty at one case study site found it very informative to learn about the state standards and recommend that other college faculty do the same. Some also learned about getting faculty in the department together to find out what others are teaching. Having a common time to talk, a practice in middle schools, has not been done at the university.
- Almost all participating faculty now are more sensitive to the complexity of education and realize that it is not easy to fix things, and one cannot take on a single dimension. One faculty noted that the experience made him "skeptical now about other faculty always blaming K–12. It is not that simple. It is a systemic issue. K–12 teachers use a mental model that they got from higher education."
- The knowledge of K–12 schools has given STEM faculty credibility, especially when teaching preservice students. In addition, it helps them better understand their students' perspectives. For example, one faculty member had assumed that students coming to her class had a calculus background. She now realizes that students were missing certain concepts in high schools and has helped them get up to speed.

Some STEM faculty acknowledged difficulties in transferring their project knowledge into their own professional lives and their feelings of being somewhat demoralized. One project is trying to help channel faculty experience into scholarly research by bringing together STEM faculty, education faculty, and Ph.D. candidates in urban education. In fact, research has emerged as a distinctive beneficiary as projects mature, even though it may be too soon to claim an impact on research. Interviews of STEM faculty revealed a few cases where the STEM faculty published articles on pedagogical research or wrote proposals on science education to the National Science Foundation (NSF) and other agencies. Participation in MSP made STEM faculty aware of the types of education research funded by NSF. There is a major chance for the faculty to learn about and to develop appreciation of social science research. One faculty member commented, "I was under the mistaken impression that pedagogical research was at a lower level and was paper thin. I now have an appreciation for the importance and depth of pedagogical research." He added that an education grant counts only about one-third as much as a research grant in the faculty tenure and rewards system. However, that might change if education grants could cover graduate student support.

- Three faculty members are redesigning an introductory course called "Mathematical Excursions" to include group problems, oral presentation, and writing assignments. Assessments of the class include a pre-post attitudinal survey, a pre-post content assessment for each unit, and a midterm and final exam to be compared to results from previous years. They hope to publish the results.
- The MSP experience has helped another STEM faculty member to evolve further in pedagogical research. She now has had two NSF course, curriculum and laboratory improvement (CCLI) grants. In one of them, she redid the biology curriculum for all undergraduates to include labs and has seen dramatic difference in how students are looking at science and data.
- A faculty member is developing an assessment and conducting an evaluation for beginning engineering students that will examine their belief in their ability to learn by asking about their confidence in handling various scenarios involving practical applications of engineering. The previous approach to accreditating engineering departments had been to count courses and numbers of students. Recently, the accreditation association has become outcome focused and asks them to show evidence about student learning.

STEM faculty also noted improved connections with peers from other IHEs, community colleges, and disciplines. Other faculty citied that the experience of working on course design, interaction with other participants, and research opportunities are beneficial. One junior faculty told us that working with large groups of teachers has expanded his horizon. "In my own research work, I work with no more than three people."

However, the impact on nonparticipating STEM faculty is likely to be minimal. We were told that nonparticipants usually do not care one way or the other. One STEM faculty said his colleagues "are probably tickled to death with what we are doing." A project director estimated that three-quarters of the faculty did not even know about the institute, even though 10 of their fellow STEM faculty are involved. "We are generally 'under the radar' within the School of Arts and Sciences." Another faculty pointed out that the lack of interest has to do with university culture—faculty usually do not care about what others are doing; "everybody is busy with their own things."

3.5 Operational Question Four: What are the effects of STEM faculty engagement on K–12 districts and IHEs? Does STEM faculty involvement as well as its effects appear to have the ability to be sustained?

As a form of partnership between K–12 teachers and IHE STEM faculty, it appears that sustainability of systematic STEM faculty involvement is dependent on future funding. Money aside, what will determine whether the activities and momentum begun through MSP will be sustained is the commitment from leadership at several levels including districts, schools, and teacher leaders, as well as interest from IHEs and STEM faculty.

Many K–12 changes that have occurred at teacher, school, and district levels can have a lasting impact. The most significant one is the change in the mindset of teachers as they continue to apply the content knowledge and use pedagogical approaches they have learned. There are some examples of emerging professional learning communities, as well as institutionalization of instructional practices, hiring processes, and resource supplies.

At the IHE level, the MSP experience will likely impact STEM faculty teaching practice and faculty collaboration. Our case studies suggest that the effect will be primarily on participants only and not on nonparticipants. We also saw many examples of changes in courses and curricula that are likely to have a lasting impact. However, those wanting to make curricular and programmatic changes have encountered obstacles if changes affect other students, STEM faculty members, or departments not involved in MSP. Finally, changing tenure and reward policies is a slow process. Case studies have found preliminary evidence about small steps made toward either elevating the status of outreach/ service directly or redefining MSP activities in terms of research or teaching. However, faculty perceptions about tenure and the reward system remained the same.

As many projects are entering a mature phase, they are inevitably forced to reflect on the questions of project impacts and its sustainability. We look at the K–12 and IHE sectors separately in Table 3-9.

Table 3-9. Perceived infrastructural changes for STEM faculty involvement (case study projects)

Area of change	P1 (C)	P2 (T)	P3 (T)	P4 (T)	P5 (T)	P6 (T)	P7 (I)	P8 (I)
K–12								
Teachers	X	X	X	X	X	X	X	X
School and district leadership	X	X		X	X		X	
IHE								
Faculty practices and culture	X	X	X	X	X	X	X	
Curricula and programs	X	X	X		X	X	X	
Reward and tenure policies								
Hiring practices	X			X	X	X		

C = Comprehensive, T = Targeted, I = Institute.

3.5.1 Changes in K–12 Districts

Case study data show that many changes at K–12, some of which can have a lasting impact, have taken place at teacher, school, and district level.

The excitement of MSP participation has reinforced teachers' will to continue to apply the content knowledge and use the pedagogical approaches they have learned. As one teacher put it, "There are changes in the mindset of teachers." In addition, MSP projects have helped open doors between teachers and IHE faculty. Teachers have become more comfortable working with STEM faculty, who are, according to one principal, "like a part of our faculty. We don't feel intimidated by them anymore." One principal pointed out, "The ongoing collaboration between faculty and teachers has become who we are—sharing decision making and collaborative learning have become our philosophy." Finally, the professional learning communities are changing traditional school structures and modes of interaction. Collegial and shared leadership is creating new norms. For example, the successful experience of one project has encouraged teachers to revive a previously defunct regional Association of Math Teachers. The association has become a way for teachers to stay in contact and is viewed as a mechanism for sustainability. With the opportunity to collaborate with others who are "thinking like you," a teacher leader said, "I am blessed with resources, I have a lot."

Critical changes cannot take place without support from the leadership, because teachers seldom have the means or time to support or transform the teaching techniques of their colleagues. According to one co-PI, "Where you have good building and superintendent support, you do well." STEM faculty noted that the building of teacher leadership will have strong implications for the sustainability of the project. In a school we visited, the principal was very supportive of the project.

He attended the summer programs for administrators and quarterly meetings, supported teachers with supplies, and communicated with project personnel. The school also worked to elicit support from parents. During parents' night, the principal and teachers explained the concept of exploratory learning, which is very different from "what moms and dads have gone through." Initially, parents expressed some apprehension and resistance, but they have become more accepting. More importantly, the concept of inquiry learning is institutionalized in the hiring process. The school makes it very clear about its support of the approach in the selection process so that it has buy-in from new teachers from their first day on the job.

Teachers and the principal in another school acknowledged improvements in their school as a result of the project. For example, the school received supplies such as books and manipulatives. It also added one more year of mathematics in the curriculum and now requires students to complete four years of mathematics in high school. A teacher leader was very optimistic about the future: "It is a done deal. Once you see it works, the attitude will change." Others are less optimistic: "It depends on who the next AP [assistant principal] is. Our current AP is very serious about it. If she is not here, teachers would probably resort to traditional way of teaching."

In another example, teacher leaders praised the project leadership for engaging with superintendents and principals from the start. The project also found a way for some poor schools and districts to get much needed resources. The team provided access to what teachers want and need, particularly technology. As a result, teachers received not only their professional development and resources such as Geometer's Sketchpad and new textbooks, but also strong backing and commitment from administrators.

Support also came from the district. For example, during a summer institute, one project paid a small stipend to participants, and the district matched it and covered child care. During the year-long follow-up, districts pay for substitute teachers. The district content specialist credited the project for "widening our horizon." Although the districts are bound by the state curriculum, the project introduced big ideas from NCTM. The school districts constantly discuss how to integrate the pacing guide and use assessment for diagnosis by student and area. A principal told us that all of the schools in the district are on the same page in terms of continuity and common assessment.

Although many teachers were eager to have a relationship with STEM faculty and said they would contact faculty via occasional emails, most of the teachers felt such interaction would cease soon after the project is completed. One teacher noted, "Personally, I would make contacts and seek help when I need answers to questions, but institutionally, money buys time for people." While the district is optimistic that the within- and across-system mechanism has been established for sustainability, it is less optimistic about the prospect of working with universities without external support.

There also were signs of reform fatigue. A principal conceded, "Frankly we are getting a little tired. There is so much training and nothing new." A PI does not see faculty working with K–12 teachers except in the context of MSP. "Five years is a long time to maintain their active engagement," he said, noting that there would need to be a specific purpose for them to stay involved with the school.

3.5.2 Changes in IHEs

Changes at IHEs may be reflected in several areas such as faculty practices and culture, curricula and programs, and reward policies and practices. Similar to the K–12 level, there are indications that the MSP experience will have an impact on STEM faculty practices. One co-PI was hopeful that "mindsets" will have changed, but he added that a lot depends on being able to prove teachers change in the ways they teach students. Teachers are trying things in their classes that they would not have thought of doing before, and they demonstrate very positive attitudes toward K–12 engagement.

In addition, faculty have gotten to know each other across departments and are more willing to work in teams. However, the reactions from nonparticipating faculty run the whole spectrum. Some are supportive, some are interested, and others are not interested at all. The high profile of the participating faculty may help gain recognition, because "people will listen." One PI added, "Especially when money is behind it, it gives legitimacy." Overall, it appears the impacts have been primarily on the participating faculty, which has to do with the institutional culture. Faculty usually do not care about what others are doing—everybody is busy with their own things. "It is a sad thing but consistent with other major universities. It may be a long time to change the culture and it certainly will not happen because of one grant," said one STEM faculty member.

Aside from changes at the individual faculty member level, some argue that changes in curricula and programs are more likely to be sustained. Below are a few examples of changes in courses, curricula, and programs:

- For one project, the restructuring of the elementary teacher preparation program has been completed, and the STEM faculty are working on reforming the curriculum for secondary teachers. The latter task is more challenging than the former and the stakes are much higher, as the courses serve multiple populations including students with other majors. As a result, the proposed changes can be political and have administrative implications. In addition, these secondary courses need buy-in from other faculty who are not participating in project.

- The STEM faculty are promoting changes in the curriculum that are already under way. The department is redoing basic courses for the major by making labs more intensive and interactive, and providing more context reinforcement. Another aspect to which the project contributed indirectly is the creation of a Teacher Academy between the college system and the municipal department of education. Students in the Teacher Academy receive full scholarships and are committed to at least two years of teaching in the school system. Many of the participants were involved the project summer program as tutors.

- Courses in the summer institute for inservice teachers are now offered at several participating universities, which hope to keep them going beyond the time of the grant for preservice teachers. Additionally, some of the practices used in the summer institute are being used in preservice K–8 courses.

- One project is working within the university on the classification of project courses. By year 2, it has completed the development of 15 courses, which were approved for graduate credit in the College of Liberal Arts and Sciences. However, the college curriculum committee balked at using a standard course catalog citation, because some committee members wanted to tag "for teachers" after each listing. The final resolution was the prefixing the graduate courses with an MSP project label. The project leadership was not pleased with this situation, as they want to eliminate the label.

- The mathematics department in another project has established a mathematics subject matter preparation program. It waives the state requirement for aspiring mathematics credential candidates to pass an examination to demonstrate their mathematics subject matter competency. Undergraduate would-be mathematics teachers who complete the subject matter preparation curriculum must still satisfy all of the other state requirements associated with teacher preparation, i.e., education/pedagogy coursework and apprentice teaching. They will need to do so in a post-baccalaureate credential program. There is interest among the STEM faculty in creating a science subject matter preparation program much like the one for mathematics, but achieving a waiver to do it is more complicated in this field. Each of the science departments has been in discussions moving toward this goal for the past year. All four of the STEM departments have a designated advisor for students who are interested in teaching, and those people serve as liaisons to the education department. Finally, many STEM faculty are becoming increasingly involved with education faculty, especially in developing curricula for STEM majors who want to also obtain a concentration in education under the several state initiatives. This interaction has intensified during the current academic year to develop new courses for those students intending to complete their degree and teaching certification in four years under the new National Math and Science Initiative (NMSI) grant.

- The last project uses curriculum development to connect preservice and inservice teaching. It requires all partner IHEs to implement a common standards-based, year-long undergraduate science course sequence for future teachers. This effort involves a revision to the general university requirements at the IHEs and affects a prerequisite for admission to elementary education program at the graduate level. The Flow of Matter and Energy in Systems course and the preservice program for elementary science teachers will be a substantive permanent change at the university and community colleges.

Although it is uniformly acknowledged that tenure and reward policies are key to encouraging STEM faculty participation, we found little change at the university level in these areas over the last four years from our eight case study projects, despite the favorable conditions created by MSP. Only one of the eight case studies articulated influencing the reward structure for IHE faculty as a goal. That project planned to convene a 15-member Council for Math, Science and Education to address the larger issues that plague education reform, systemic problems, and specific issues arising from the project's operation. Potential issues include discussions of reward structures for IHE faculty and K–12 teachers, as well as institutional change and sustainability. However, this important macro side of the proposal has never really taken off. Exhibit 3-5 shows the experience of a non-case-study project that has made considerable strides in reforming its tenure and reward policy across the university system.

For the case study projects, we saw some incremental changes in practices at department levels. For example, one lecturer has worked with the MSP from the beginning. She recently had her five-year review and was certain that her work with the project was responsible for a "larger than normal" salary increase, as the review committee highlighted that work in their written report. They indicated that she did not have to become involved in this extra activity but were impressed that she did. We also heard stories that outstanding MSP participants were denied promotion because of lack of research. In one case, the faculty member felt that her involvement with MSP was made the scapegoat for not obtaining tenure—it was really because of personal reasons.

Exhibit 3-5. An example of tenure and reward policy change

One non-case-study MSP project has made notable progress in reforming the tenure and reward policies. The Partnership for Reform in Science and Mathematics (PRISM) identified the area of providing a reward structure in universities as one of the 10 goals (Kutal et al., 2006). In strategy 10, the project will "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." By engaging all levels of the University System of Georgia from individual faculty members, departments, schools, and colleges to the board of regents, changes were made to the regent policies that include the following language:

Board of Regents' approval of University System of Georgia institutions to prepare teachers includes the expectation that public colleges and universities with a teacher preparation mission will collaborate with the K–12 schools. University System institutions that prepare teachers will support and reward all faculty who participate significantly in approved teacher preparation efforts in school improvement through decisions in promotion and tenure, pretenure and posttenure review, annual review and merit pay, workload, recognition, allocation of resources, and other rewards. Participation in teacher preparation and in school improvement may include documented efforts of these faculty in:

- *Improving their own teaching so as to model effective teaching practices in courses taken by prospective teachers;*
- *Contributing scholarship that promotes and improves student learning and achievement in the schools and in the university; and*
- *Collaborating with public schools to strengthen teaching quality and to increase student learning.*

In the guidelines published in the Academic Affairs Handbook, the university system further defines teaching, scholarship, and service, each of which contains examples of faculty work. Specifically, scholarship includes the Scholarship of Teaching and Learning, Scholarship of Engagement, and Scholarship of Discovery. As a result, faculty throughout the state are now considered for promotion and tenure decisions based on a broader definition of scholarship. It is nevertheless a much longer process, taking over three years to accomplish, than the anticipated one year in the proposal. It is even more important to see how the policy is being implemented across the state.

Departmental changes were more likely to take place when department chairs were involved in MSP. One PI, who is also the department chair at a research university, said, "As long as I am chair, it will play positively in terms of tenure and review." That is not true, however, with all projects. Another PI who has been the chair of the department said that there was never any intention to change the promotion and tenure criteria in his department. Efforts have been made to redefine MSP activities in terms of research or teaching. For example, up to the second year of this study, research was identified only as an area of STEM faculty activity in one of the eight case study projects. Our latest round of visits found that at least five projects have STEM faculty conduct research. However, the actual implementation can be complex.

- In his evaluation of faculty members, a mathematics department chair who has been directly involved in the project from the beginning defined MSP as "multi-disciplinary and collaborative work." Faculty get course reductions. The college considered it in tenure and promotion decisions because it crosses multiple components. In addition to outreach, research in mathematics education is counted as "application of math" similar to its applications in engineering or statistics. However, few participating faculty members have based their research agenda on their outreach activities. The chair added "if they do that, I will argue for it...I'd prefer to count it as research contribution because it is more highly regarded in the community."

- In another case, a department chair is not directly involved in the project but has provided moral support and space. Although we heard that scholarship of teaching is recognized at the university, we could still sense that it is in a somewhat undefined territory from the chair's comment. "It is difficult. Although service is valued, research weighs heavily. We have not totally figured it out. It is tricky to contextualize. People are always suspicious about publications and it has to be on a case-by-base basis with more justification." He added, "There is a lot of sympathy. The ongoing focus has to do with the proportion of academic involvement in the outputs. The administration is reasonably receptive." The university recently launched a responsive research network for STEM education with MSP faculty highly represented. The network was established for faculty with interest in scholarship of teaching and learning.

- The third project has not seen major changes because all of the faculty are tenured. However, the language is being formalized regarding tenure and promotion in all departments stating that education research will be reviewed the same as disciplinary research.

Another area of change is in hiring practice. For example, a department chair noted that there is a new faculty slot added for STEM education. "Right now, there is not a critical mass, but I am not surprised to see it develop into a new sub-program. It will fit in the department nicely." Similarly, for another project, the department is hiring a tenure-track STEM educator who will spend 80 percent of his/her time in disciplinary research and 20 percent in education research. "This would have been laughed away five years ago." But he felt that people were starting to understand. For the third project, two STEM education faculty are being hired at the lead institutions, which may be the result of MSP or increased awareness within departments of the need for STEM education insights. Several departments in another project have made hiring discipline/education faculty—e.g., doctorates in physics education, mathematics education, etc.—a priority. In one instance, a department chair asked his faculty to make a choice between beginning a search for a biosciences education faculty member or a marine biologist. The educator position was chosen. Those departments that are electing to move in this direction are finding it to be an "exceedingly difficult and competitive" undertaking because of both the lack of people with these credentials and the increasing number of IHEs attempting to attract those who are available.

However, as we kept probing STEM faculty perception about changes in university tenure and reward systems, we found little movement in their views. One STEM faculty member observed: "Any consideration of coupling the three areas (research, teaching, and service) as equal is moving slower than a glacier." Changes regarding institutional reward and tenure policies will continue to be slow and can be controversial even among the participating STEM faculty. As one noted, "I am ambivalent about it. Achieving tenure through outreach will create different attitudes. I don't think outreach should be an easy way to get tenure." One co-PI said that IHE policies have not changed, but a foothold has been established in the university for thinking about MSP style involvement "Policies, no; mind sets—there has been a change."

3.5.3 Sustainability

A fundamental question is what sustainability should mean for MSPs. Does it mean keeping the same faculty and IHEs working with the same districts, schools, or teachers? Or does it mean that IHEs will work with cohorts of teachers and administrators over time just as they work with cohorts of college students? Probably the major question is the nature of sustainability—what would good sustainability mean and how should it look? What are the relative roles of the IHEs and school districts? How will STEM faculty reconcile their disciplinary research and pedagogical research in the discipline, if they need to be reconciled?

MSP funding will end sooner or later. Many STEM faculty expressed interest in working with similar types of programs or activities. One project is trying to seek seed money for the summer camp to tap into the urban market around the city. They were beginning to think of themselves as venture capitalists relative to obtaining new funding to do more work. One team of STEM faculty within a project is planning to forego money to continue working the schools. While most STEM faculty expressed an interest in continuing to work on MSP-like activities, they realize that without MSP resources, the activities will not be operating as extensively. However, many are hopeful that when the project is complete, things will be in place, the process will go on, and the changes will be self-perpetuating.

Respondents unanimously acknowledged that sustainability is "the hardest thing" and "it is a struggle to sustain anything." Perhaps the most sustaining element is the change of mindsets for both K–12 teachers and IHE faculty. Throughout case studies, we saw evidence that STEM faculty have increased the content knowledge of teachers and, to some extent, influenced positive changes in instructional practices and inspired teachers to embrace such changes and work together. What is least clear is exactly how or if STEM faculty involvement will translate into student achievement improvement. Based on our observations, we feel that sustainability of STEM faculty involvement with inservice teachers will probably not continue formally on a large scale, but may continue in some very supportive districts. With the completion of the project, teachers will be faced with the task of self-sustaining any project-related improvements deemed worthwhile. Unfortunately, this task becomes more and more difficult with day-to-day challenges they face such as lack of support and teacher turnover.

For STEM faculty, the largest impacts are the effect on participants. However, given the culture of IHE, the spillover effects on nonparticipating STEM faculty are minimal. Changes in courses and curriculum are likely to be sustaining. In general, changes in tenure and reward policies are less than expected, which again reflects the observations of some respondents that "universities are deeply entrenched places."

As a form of partnership between K–12 teachers and IHE STEM faculty, it appears that sustainability of systematic STEM faculty involvement is "dependent on future funding." Money aside, the commitment from leadership at several levels will determine whether the activities and momentum begun through MSP will be sustained. Superintendent leadership is surely essential to set the tone and can attract local funding, but it is the principal who provides instructional leadership for the school and must encourage teachers to become involved. And finally, it is the teacher leaders who must rally the teachers to take advantage of the opportunities available. Philosophical and political issues also need to be sorted out. One PI noted, "I can see it sustained for the next 15 years but it can also go away quickly. There are a lot of internal politics and turf battles in terms of who gets the credits." Although STEM faculty can make a significant contribution in the change process, they are not the only key to solving the problem. Systematic changes require commitment and capacity from the whole community.

Reflecting on their MSP experience, evaluators of one project commented, "As long as people have genuine interest and concerns, we want to see them continue to be involved." While many MSP projects may not continue beyond NSF funding, their legacies are joined with the other similar initiatives. They have been important in helping to bring new programs and funding, just as they stood on the shoulders of other people and programs that came before. If STEM faculty and other participants continue to be involved in math and science education at both the K–12 and IHE levels, that would indeed be a positive outcome.

Summary and Implications 4

In this section, we summarize findings from year 4 of the study. We also discuss implications for our remaining study.

4.1 Summary of Findings

For the MSP projects, the report provides good news, bad news, and uncertain news. The good news comes from participants. K–12 teachers reported benefits from improved approaches to teaching and learning, increased knowledge of subject matter content, and increased confidence both as teachers and as colleagues with IHE faculty. The STEM faculty also benefited from new ideas about teaching and learning, more knowledge of the K–12 education system, and a broader understanding of education overall. The value of collaboration and teamwork are broadly acknowledged by all participants. The bad news continues to be that relatively few faculty members in the university STEM fields are willing to participate, few benefits extend beyond those faculty who are direct participants, and few systemic changes have been made in IHE systems, especially the reward structure. As an individual change process, MSP seems to be successful for many participants; as an organizational change process, MSP seems to be less successful. A perennial theme of our reports over the years is the power and intractability of the university reward system in resisting change. However, we observed some incremental changes that may have long-term impact. And finally, the uncertain news remains in the impact on student achievement.

STEM faculty engagement is a unique feature of MSP. Proponents who are looking for a silver bullet to solve all STEM education woes will probably be slightly disappointed at the results. However, for opponents who think STEM faculty are irrelevant in the picture, their criticisms are not substantiated either because we clearly see the benefits for many involved. What we have gained from this investigation is a better understanding and appreciation of the complexities of the challenges ahead. While we see a meaningful role for STEM faculty, we also recognize that tackling the challenges requires systemic efforts and improved capacity from the whole community of K–12 teachers, administrators, IHE education faculty, students and parents, and policymakers.

As in previous years, the report highlights the fact that there is no "typical" MSP project or STEM faculty involvement. Projects differ in size, type of institutions involved, types of K–12 and IHE faculty involved, and impact. While the projects share some similarities, the biggest commonality is the desired outcome, not the context and the approaches. What we hope to convey is a sense of complexity in STEM faculty involvement and its impacts. Furthermore, we observed many parallels between the K–12 system and the IHE system, and between the K–12 teachers' learning and IHE faculty's learning. All of these further pointed out that while the contexts may be different, the issues are the same. We group preliminary findings in four general areas as follows.

What is the IHE policy context for STEM faculty involvement? What have the projects done to engage and support STEM faculty?

- Traditional reward structures and faculty perceptions about the status associated with different types of engagement are considered major barriers for faculty involvement in most MSP-like endeavors. While the majority of the IHEs recognized service or outreach, such activities are generally considered to be a distant third in priority after research and teaching. This presents a serious institutional problem and a major roadblock to involving faculty from the STEM disciplines. Some institutions specifically discourage junior faculty from participating in these activities so that they do not have to sacrifice time that could otherwise be spent on research. The current policy environment perpetuates the general public impression that IHEs are intentionally disengaged from the most pressing needs of our society. A realignment of faculty priorities and a different set of categories are required. The IHEs need to find persuasive and legitimate alternatives to "service" and even "outreach." The fact that several IHEs define research from MSP activities as "scholarly" reflects an emerging trend to recognize that teaching and engagement with the serious local and national challenges of mathematics and science in K–12 are discipline-based scholarship activities that require the attention of our best STEM faculty.

- Other conditions are critical to STEM faculty involvement. At the IHE level, such conditions may include previous experience working with K–12 sectors and the hiring practices. At the K–12 level, a key issue is support from the leadership. State and local policies, coupled with changes in infrastructure and funding, may also enhance or impede the implementation and impact of MSP projects and STEM faculty involvement.

- Although tenure and reward policies are critical to STEM faculty engagement, most MSP projects were not specifically designed to tackle that issue. Nevertheless, there are a number of effective strategies a project can use to increase STEM faculty engagement in the absence of changes in tenure and reward policies. At the project level, both extrinsic and intrinsic incentives need to be created. The former may involve providing release time and stipends for faculty members, and the latter often include providing professional development to faculty to enhance their understanding of K–12 perspectives and pedagogical issues, building partnerships among participants, as well as demonstrating sensitivity and flexibility to faculty needs.

- Extrinsic incentives are well understood, as all of the case study project offer stipends and five provide release time. These incentives were established at the beginning of the projects and have remained consistent over time. The intrinsic piece, especially for the project to make the case and to create intellectual connection for the need for substantive STEM faculty work with K–12 teachers, is often underestimated. While most projects recognized the importance of building partnership early on, many projects have a steep learning curve throughout the years about the values of providing professional development for STEM faculty, as well as demonstrating sensitivity and flexibility to their needs. Case studies also highlight the needs for the projects to use evidence-based evaluation to guide STEM faculty engagement.

Has there been any change in number of STEM faculty, extent and variety of involvement, and nature of collaboration between STEM faculty and other participants?

- The extent of STEM faculty involvement in MSP has shown little change over time. With one exception, the scope of STEM faculty involvement established in the initial stage of the projects remained unchanged.

- STEM faculty have participated in a variety of MSP activities such as teaching inservice teachers, working with K–12 and university students, developing curriculum, managing projects, and conducting research. The most common activities are conducting workshops with K–12 teachers that increase general content and/or pedagogical knowledge. However, the fastest growing area is research, particularly pedagogical research due to both top-down and bottom-up influences.

- Case studies show that STEM faculty members' working relationships with other participants such as education faculty, K–12 teachers, and teacher leaders are critical not only to making MSP a more positive experience for participants, but also to the success of MSP projects. Initial site visits found that the relationship between STEM and education faculty were collegial in some cases and problematic in others, depending as much on personalities as on disciplines. Data from year 4 show that the relationships are improving over time. STEM faculty continue to enjoy a collegial relationship with teacher leaders. The quality of collaboration between STEM faculty and K–12 teachers has been generally rated high by both groups. A key to the success of these relationships is mutual respect and ongoing communication and dialogue.

What are the effects and evidence of STEM faculty engagement on teachers, students, and STEM faculty themselves?

- Initially, many STEM faculty expected to see positive impacts on teacher content knowledge. As the projects mature, there is an increasing realization among faculty that pedagogical skill is at least as important as content knowledge for K–12 teachers. Throughout the past four years, teachers reported learning of content and, especially, pedagogy and increasing confidence. However, caution needs to be taken when interpreting the self-reported data, as observations of teacher instruction tends to suggest that the real changes in instructional practices are not as great as the self-report would indicate. In addition, STEM faculty involvement is rarely seen as the sole or even the main contributor to the changes reported.

- Respondents continue to be less certain about direct impact on student achievement from the very beginning. Many hope that the effect on teachers will filter down to students. Despite concern about state assessments and attribution, many are anxious to use state assessment results to validate project success. However, even though there is evidence showing that student achievement is going up toward the end of the projects, few are comfortable with attributing the progress to STEM faculty involvement either because STEM faculty are primarily working with teachers and not students, or because of many other confounding variables. Most respondents pointed out that other types of student impact, such as student attitudes and ability to think and understand deeply, are equally important.

- Perhaps the biggest surprise is that participating STEM faculty increasingly acknowledged learning from the MSP experience in terms of becoming better teachers themselves, understanding K–12 perspectives, being exposed to teamwork and connections, and conducting research activities. The improvement of teaching in ways that are more active, collaborative, and student-centered for the STEM faculty is one of the unintended consequences of the MSP activity.

What are the effects of STEM faculty engagement on K–12 districts and IHEs? Does STEM faculty involvement as well as its effects appear to have the ability to be sustained?

- As a form of partnership between K–12 teachers and IHE STEM faculty, it appears that sustainability of systematic STEM faculty involvement is dependent on future funding. Money aside, what will determine whether the activities and momentum begun through MSP will be sustained is the commitment from leadership at several levels including districts, schools, and teacher leaders, as well as interest from IHEs and STEM faculty.

- Many K–12 changes that have occurred at teacher, school, and district levels can have a lasting impact. The most significant one is the change in the mindset of teachers as they continue to apply the content knowledge and use pedagogical approaches they have learned. There are some examples of emerging professional learning communities as well as institutionalization of instructional practices, hiring processes, and resource supplies. However, sustaining the effects depends on commitment from schools and districts. With the completion of the project, teachers will be faced with the task of self-sustaining any project-related improvements deemed worthwhile. Unfortunately, this task becomes more and more difficult with the day-to-day challenges such as lack of support and teacher turnover that they face.

- At the IHE level, the MSP experience will likely impact STEM faculty teaching practice and faculty collaboration. Our case studies suggest that the effect will be primarily on participants only, not on nonparticipants. We also saw many examples of changes in course and curriculum that are likely to have a lasting impact. However, curriculum and programmatic changes have encountered obstacles if they affect other STEM faculty members, or departments not involved in the initiative. Finally, changing tenure and reward policies is a slow process. Case studies have found evidence about small steps at the departmental level made toward either elevating the status of outreach/service directly or redefining MSP activities in terms of research or teaching.

4.2 Implications for Future Study

Our project received a one-year no-cost extension. During the final year of the study, we will conduct additional analysis of MIS data, secondary analysis of project data and reports from case study projects, as well as an update of our literature review.

Table 4-1. Year 5 study activities

Activity	Timeline
Analysis of the MIS data	May–August 2008
Analysis of project reports	July–August 2008
Literature review	June–September 2008
Site visit	October 2008
Year 5 report	December 2008–March 2009
Dissemination (1–2 conference presentations)	October 2008–April 2009

Literature review. We will provide an updated systematic literature review of the nature and impact of STEM faculty involvement based on literature from both within and outside the context of MSP. The scope of the review will be broad, covering literature from MSPNet and electronic databases such as ERIC.

Site visits. We plan to visit PRISM—the only IHE that has made significant change in tenure and reward policy as a result of MS—to gather additional data, specifically with regard to the process, implementation, and effect of the new tenure and reward policies. We will continue to digest and reflect on the case study data we have collected as we analyze other data.

Analysis of MIS data. Analysis will be both descriptive and correlational. Descriptive analyses will continue to look at STEM faculty responses to the IHE participant survey in 2006–07. Comparisons with data from previous years will be made when appropriate, providing evidence of trends. Correlational analysis will build on the analysis in year 3 by including the longitudinal component of school-level student outcome data from multiple years. Additionally, we will explore the relationships between student achievement and STEM faculty involvement, as well as specific or combinations of practices.

Analysis of project data. This task will be conducted in a much larger scale. Based on our understanding of the nature of data collection within each project, we will expand the scope of our primary analysis from selected projects while continuing to incorporate evidence from project evaluations. Where possible, our secondary analysis will expand beyond the eight case study projects by including data from non-case-study projects.

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Appendix A. Advisory Panel and Site Visitors in Year 4 (in alphabetical order)

Advisory Panel

Jerry Gaff, Senior Scholar, Association of American Colleges and Universities, Washington, DC

Laurie A. Fathe, Associate Provost for Education Improvement and Innovation, George Mason University, Fairfax, VA

David Kaplan (statistical consultant), Professor of Education, University of Wisconsin, Madison, WC

Alfred Manaster, Professor of Mathematics, University of California, San Diego, San Diego, CA

H. Eugene Rice, Senior Scholar, American Association for Higher Education, Washington, DC

STEM Site Visitors

John Kern, II, Associate Professor of Mathematics and Computer Science, Duquesne University, PA

Alexander Hahn, Professor of Mathematics, University of Notre Dame, Notre Dame, IN

Rhonda Hatcher, Assistant Professor of Mathematics, Texas Christian University, TX

Nancy L. Jestel, Analytical Chemist, GE Plastics, Selkirk, NY

Katrina Palmer, Assistant Professor of Mathematical Sciences, Appalachian State University, NC

Eric Rawdon, Assistant Professor of Mathematics, St. Thomas University, St. Paul, MN

Peggie Weeks, Metallurgical Consultant, PrO Unlimited/Corning Inc., NY

Westat Site Visitors

Joy Frechtling, Joseph McInerney, Joan Michie, Glenn Nyre, John Wells, Xiaodong Zhang (PI)

APPENDIX B. SITE VISIT PROTOCOLS[1]

PI/PD INTERVIEW PROTOCOL

Respondent: MSP:

Interviewer: Institution:

Date: Duration:

Thank you for taking the time to talk to us about your MSP. We spoke to you last year about the extent and effect of STEM faculty involvement in your project. This is the final year of our study. We are interested in changes and sustainability with regard to STEM faculty engagement. The interview will take about 60 minutes. We won't identify you or your project by name in our report.

STEM faculty involvement and relationships with other players

1. During the entire course of the project, have you noticed any changes in STEM faculty's working relationships with other project participants a. other STEM faculty, b. education faculty, c. teacher leaders, d. K–12 teachers, e. pre-service students? (*probe each one where applicable*) If yes, please describe. [**short-term outcomes/F2**]

2. Based on your experience, what is the key to engaging STEM faculty? [**activities/F1**]

3. Which STEM faculty involvement activities were most successful? What activities were least successful? Could you give us some examples of both? [**activities/F1**]

Institutional policies and resources

4. During the course of the project, have there been any major changes in a. departmental, b. university or c. system (if applicable) policies and practices regarding tenure and rewards that may affect STEM faculty involvement? If yes, please describe. [**interim outcomes/F3**]

5. (*If applicable*) Did the project do anything to change these policies and practices? If so, please describe. [**short-term outcomes/F2**]

6. We want to learn more about the broader context of your project implementation. Were there external factors that have affected STEM faculty involvement and your project implementation (*e.g. other institutional policies, state standards and testing, NCLB, financial and political context, business/ community involvement*)? If yes, in what ways? [**context**]

Perspectives about STEM faculty involvement impact

7. Is there any effect of STEM faculty involvement on teacher quality (e.g., content knowledge, pedagogical skills, confidence)? If yes, what is the evidence? [**interim outcomes/F3**]

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[1] The content in the brackets is provided to the site visitors to help map the question to the logic model.

8. Is there any effect of STEM faculty involvement on K–12 student achievement? If yes, what is the evidence? [**interim outcomes/F3**]

9. How has the project involvement affected STEM faculty themselves (*e.g. incorporating new teaching and learning techniques in their own preservice and disciplinary instruction AND in working with K–12)*? [**interim outcomes/F3**]

10. Has STEM faculty involvement in MSP had any broader effect on your institution in terms of a. attitude toward K–12 engagement, b. nature of course, curriculum and program offerings, c. collaboration among faculty from different disciplines? If yes, what is the evidence? [**interim outcomes/F3**]

11. Will STEM faculty involvement and the resulting capacity be sustained after your project is completed? If yes, in what ways? What would be needed to enhance sustainability? [**long-term outcomes/F4**]

12. What would you do differently in regard to STEM faculty engagement if you have the chance to do the project all over again? [**activities/F1**]

13. If you were giving advice to NSF, what would you recommend as the most effective way to promote STEM faculty engagement? [**long-term outcomes/F4**]

14. Are there other things you'd like to discuss about STEM faculty participation in the MSP or its results?

Thank you.

STEM FACULTY INTERVIEW PROTOCOL

Respondent:	MSP:
Interviewer:	Institution:
Date:	Duration:

Thank you for taking the time to talk to us. In previous years, we talked about the extent and effect of STEM faculty involvement in MSP. This is the final year of our study. We are primarily interested in any changes that have occurred and sustainability issues. The interview will take about 60 minutes. We won't identify you or your project by name in our report.

1. During the course of the project, have there been any changes in your project involvement in the following areas: a. inservice training, b. preservice teaching, c. curriculum development for K–12 and or IHE, d. research (disciplinary or STEM-ed), e. student recruitment (for both STEM undergraduate and preservice students) and f. project management? (*probe each one if applicable*) [**short-term outcomes/F2**]

2. During the course of the project, have there been any changes in the project's approach to providing support for your participation (*e.g. incentive, professional development, support*)? If yes, please describe. [**activities/F1**]

3. During the entire course of the project, have there been any changes in departmental and university policies and practices that affected your involvement? If yes, please describe. [**interim outcomes/F3**]

5. What factors have facilitated your involvement? What factors have hindered your involvement? What can be done to overcome the hindrances? [**activities/context/F1**]

6. How do you assess your working relationship with other project participants a. education faculty, b. other STEM faculty, c. teacher leaders, d. K–12 teachers, e. preservice students, f. K–12 students? (*probe each one where applicable*). Have these relationships changed during the course of the project? [**short-term outcomes/F2]**

7. How have you been affected by your participation in MSP personally and professionally? What have you gained or lost? [**interim outcomes/F3**]

8. Do you think your involvement affected changes in a. K–12 teachers, b. K–12 students, c. preservice and/or STEM undergraduates; d. your institution, (*probe each one*)? If yes, what is the evidence? [**interim outcomes/F3**]

9. What capacity has been built that will be sustained after the project is completed? What level of involvement in STEM education will you sustain? What would be needed to enhance sustainability?[**long-term outcomes/F4**]

10. What have you learned about STEM faculty and its role in K–12 reform that you did not know at the beginning of the project?

PROJECT EVALUATOR (INTERNAL/EXTERNAL) INTERVIEW PROTOCOL

Respondent: MSP:

Interviewer: Institution:

Date: Duration:

Thank you for taking the time to talk to us. Our research project is supported by National Science Foundation's Math and Science Partnership (MSP). This is the final year of our study. We are primarily interested in your views and observations on the key issue of STEM faculty involvement in MSP. The interview will take about 45 minutes. We won't identify you or your project by name in our report.

1. Has the project evaluation addressed STEM faculty engagement? If yes, in what ways (*e.g., what types of data were collected and how they were analyzed)*? [**activities/F1**]

2. During the course of the project, have you noticed any changes in STEM faculty's working relationships with other project participants (*e.g. education faculty, other STEM faculty, teacher leaders, K–12 teachers, pre-service students*)? If yes, please describe. [**short-term outcomes/F2**]

3. Based on your experience, what is the key to engaging STEM faculty? [**activities/F1**]

4. Which STEM faculty involvement activities were most successful? What activities were least successful? Could you give us some examples of both? [**activities/F1**]

5. Is there any effect of STEM faculty involvement on teacher quality (e.g., content knowledge, pedagogical skills, confidence)? If yes, what is the evidence? [**interim outcomes/F3**]

6. Is there any effect of STEM faculty involvement on K–12 student achievement? If yes, what is the evidence? [**interim outcomes/F3**]

7. How has the project involvement affected STEM faculty themselves? [**interim outcomes/F3**]

8. Has STEM faculty involvement in MSP had any broader effect on the IHEs in terms of a. attitude toward K–12 engagement, b. nature of course, curriculum and program offerings, c. collaboration among faculty from different disciplines, d. tenure and reward policies? If yes, what is the evidence? [**interim outcomes/F3**]

9. Do you think STEM faculty involvement and the resulting capacity be sustained after the project is completed? If yes, in what ways? What would be needed to enhance sustainability [**long-term outcomes/F4**]

10. *(If applicable)* From the evaluation point of view, what have you learned about evaluating STEM faculty involvement? [**activities/F1**]

11. Are there other things you'd like to discuss about STEM faculty participation in the MSP or its results?

Thank you.

STEM CHAIR INTERVIEW PROTOCOL

Respondent:	MSP:
Interviewer:	Institution:
Date:	Duration:

Thank you for taking the time to talk to us about MSP that some of your faculty are participating and institutional policies related to it. The Math and Science Partnership (MSP) is a major research and development effort on the part of the National Science Foundation that is designed to improve K–12 student achievement in mathematics and science. We are examining the extent and effect of mathematics and science faculty involvement in MSP, which is the central premise of this national initiative. The interview will take about 30 minutes. We won't identify you or your project by name.

1. How many faculty members do you have in the department? How many STEM faculty in your department/school are working for the project this year? [**short-term outcomes/F2**]

2. To what extent have you been involved in or informed about the MSP activities? If involved, in what ways are you supportive of the MSP involvement? [**context**]

3. **At your university, how does faculty involvement in MSP activities get characterized (i.e. service, outreach, scholarly contribution/STEM education research or others)?** [context]

4. Are there any university or department policies that may encourage or discourage MSP-like activities for the faculty? If yes, how? [**context**]

5. How do your faculty in general perceive this type of involvement? [**context**] Do you feel that this perception has changed since MSP project came to campus? [**long-term outcomes/F4**]

6. Are there any types of STEM faculty more interested in this type of activities than others? If yes, please describe.[**short-term outcomes/F2**]

7. Does STEM faculty involvement in MSP have any broader effect on your institution in terms of the following: a. attitude toward K–12 engagement, b. nature of course, curriculum and program offerings, c. collaboration among faculty from different disciplines, and d. tenure and reward policies? If yes, what kinds of effects have you noticed? [**interim outcomes/F3**] Do you think the effect can be sustained after the project is completed? [**long-term outcomes/F4**]

8. Do you think institution policies and reward structure should change to encourage MSP-like activities? If yes, what does it take in order to sustain this type of involvement? [**long-term outcomes/F4**]

9. Are there other things you'd like to discuss about STEM faculty participation in the MSP or its results?

Thank you.

EDUCATION FACULTY INTERVIEW PROTOCOL

Respondent: MSP:

Interviewer: Institution:

Date: Duration:

Thank you for taking the time to talk to us. Our research project is supported by National Science Foundation's Math and Science Partnership (MSP). We are examining the extent and effect of mathematics and science faculty involvement in MSP, which is the central premise of this national initiative. We've talked to some of education faculty about their experience in working with STEM faculty in previous years. This is the final year of our study. We are particularly interested in any changes in your experience. The interview will take about 30 minutes. We won't identify you or your project by name in our report.

1. What are your responsibilities in the MSP?

2. In what ways do you work with math and science faculty in the project? Have these changed over time? **[short-term outcomes/F2]**

3. What is your assessment of the collaboration? Did you encounter any surprises or challenges in that collaboration? How did you resolve these? **[short-term outcomes/F2]**

4. Has the project done anything to facilitate the collaboration? **[activities/F1]**

5. What have you learned through the collaboration?**[short-term outcomes/F2]**

6. How have you been affected by working with STEM faculty in MSP personally and professionally? **[interim outcomes/F3]**

7. Do you think the project has resulted in improved teacher content knowledge and pedagogical skills? If yes, what is the contribution of STEM faculty? Can you give some examples? **[interim outcomes/F3]**

8. Do you think the project has resulted in K–12 student achievement? If yes, what is the contribution of STEM faculty? Can you give some examples? **[interim outcomes/F3]**

9. Are there other things you'd like to discuss about STEM faculty participation or its results?

Thank you.

PRESERVICE CANDIDATE/STEM UNDERGRADUATE GROUP INTERVIEW PROTOCOL

Respondent:

Interviewer:

Date:

MSP:

Institution:

Duration:

Thank you for taking the time to talk to us. The Math and Science Partnership (MSP) is a major research and development effort on the part of the National Science Foundation that is designed to improve K–12 student achievement in mathematics and science. We are examining the extent and effect of mathematics and science faculty involvement in MSP, which is the central premise of this national initiative. This is the final year of our study. We are particularly interested in your personal experience with math and science faculty such as (*STEM faculty names)*. The interview will take about 20 minutes.

1. Will you please tell us something about yourself—*raise hands for count* (*e.g., degree program, year in the program, prior classroom experience*)?

2. Was the class/session we just observed typical of this class? If yes, in what ways? If not, why not? [**interim outcomes/F3**]

3. What did you think about the content that was presented? (*e.g. Was it too easy? Over your head?)* [**interim outcomes/F3**]

4. What did you think about the way the lesson was presented (*i.e., pedagogy*)? (*Preservice only)* Will you be able to apply that method of presentation in the classroom in the future? In what ways? [**interim outcomes/F3**]

5. Are faculty in math and science departments different from education faculty? In what ways? *(e.g. content, pedagogy, class requirement)* [**interim outcomes/F3**]

6. *(Preservice only)* To what extent do you think higher education math and science faculty involvement will help you to become a better teacher and improve student achievement in the future? [**long-term outcomes/F4**]

8. *(STEM undergraduates only)* Do you have future plans to teach? [**long-term outcomes/F4**]

9. Do you have any other comments?

Thank you.

INSERVICE TEACHER/TEACHER LEADER INTERVIEW PROTOCOL

Respondent:	MSP:
Interviewer:	Institution:
Date:	Duration:

Thank you for taking the time to talk to us. The Math and Science Partnership (MSP) is a major research and development effort of the National Science Foundation that is designed to improve K–12 student achievement in mathematics and science. We are examining the extent and effect of mathematics and science faculty involvement in MSP, which is the central premise of this national initiative. This is the final year of our study. We are particularly interested in your personal experience with math and science faculty in this project. The discussion will take about 45 minutes. We won't identify you or your project by name in our report.

1. Was the lesson we observed typical of most of your lessons? If yes, in what ways? If not, why not[**interim outcomes/F3**]?

2. Will you please tell us something about yourself (*e.g., grade level, years of teaching experience, degree, math/science training, reason/motivation to participate, district/project incentive*)?

3. Please tell us about your involvement in this project. [**context**]

4. In what ways have you worked with math and science faculty in the project (*names some STEM faculty here as example*)? (*e.g. teacher leader, professional development, curriculum design, mentoring*) [**short-term outcomes/F2]**

5. How do you assess your working relationship with STEM faculty? [**short-term outcomes/F2**]

6. Are math and science faculty in this project different from other professional development providers you've experienced? If yes, in what ways? [**interim outcomes/F3**]

7. To what extent do you think higher education math and science faculty involvement in this project has helped you to become a better teacher (*e.g. content knowledge, pedagogy, confidence*)? What is the evidence [**interim outcomes/F3**]?

8. To what extent do you think higher education math and science faculty involvement in this project has helped improve student achievement? What is the evidence? [**interim outcomes/F3**]

9. Are there things that might make the contributions of math and science faculty more useful and meaningful to you as a teacher? [**interim outcomes/F3**]

10. In what ways has the involvement from you and your colleagues in this project changed your school? What is the evidence? [**interim outcomes/F3**]

11. Do you think the collaboration with STEM faculty will be sustained after the project is completed? What would be needed to enhance the sustainability? [**long-term outcomes/F4**]

12. What do you know about working with university math and science faculty now that you did not know at the beginning of the project? [**short-term outcomes/F2]**

PRINCIPAL INTERVIEW PROTOCOL

Respondent(s): MSP:

Interviewer(s): Institution:

Date: Duration:

Thank you for taking the time to talk with us. Our research project is funded by the National Science Foundation, under its Math and Science Partnership Program, which also funds [project name]. We are examining the extent and effect of higher education mathematics and science faculty involvement in MSP, which is the central premise of this national initiative. This is the final year of our study. We are particularly interested in your insights concerning the impact this program is having on your school. The interview will take about 45 minutes. We won't identify you or your project by name in our report.

1. How long have you been the principal of this school? [**context**]

2. Has your school been involved in any recent reforms that involve math and science university faculty? If yes, please describe. [**context**]

3. How long has your school been involved with the [project name]? What types of project activities have taken place at your school? [**context**]

4. What has been your involvement with project activities at your school or off-site? (*e.g. encouraging teachers to participate, participating yourself, observing, scheduling, project planning or management)* [**interim outcomes/F3**]

5. Has there been any change in teacher participation (*e.g. number of teachers)* over time? If yes, is teacher turnover due to change in the project or to other program changes in your district/state? [**context**]

6. Can you describe teachers' reactions to the project activities? *(e.g. attitudes, level of satisfaction)* Have you noticed changes in their reaction over time? [**interim outcomes/F3**]

7. Have you worked with university math and science faculty in this project? Are they different from other professional development providers who have worked with your school? If yes, in what ways? [**interim outcomes/F3**]

8. What is your assessment of the collaboration with university math and science faculty and teachers in your school so far? Have you encountered any surprises or challenges? [**interim outcomes/F3**]

9. Do you think the project has improved teacher content knowledge, pedagogical skills and professional attitude in your school? What is the contribution of university math and science faculty? If so, can you provide some examples? [**interim outcomes/F3**]

10. Do you think the project has resulted in improved student achievement in your school? What is the contribution of university math and science faculty? If so, can you provide data or give some examples? [**interim outcomes/F3**]

11. Do you think the collaboration with STEM faculty can be sustained after the project is completed? What would be needed to enhance the sustainability? [**long-term outcomes/F4**]

12. Has there been any impact of the project at the district level? [**interim outcomes/F3**]

13. Are there other things you'd like to add regarding STEM faculty participation or its results?

DISTRICT CONTENT SPECIALIST INTERVIEW PROTOCOL

Respondent(s): MSP:

Interviewer(s): Institution:

Date: Duration:

Thank you for taking the time to talk with us. Our research project is funded by the National Science Foundation, under its Math and Science Partnership Program, which also funds [project name]. We are examining the extent and effect of higher education mathematics and science faculty involvement in MSP, which is the central premise of this national initiative. This is the final year of our study. We are interested in your views on this issue from the district perspective. The interview will take about 30 minutes. We won't identify you or your project by name in our report.

1. To what extent has the school district been involved in this project? [**context**]

2. How has teacher participation in the project changed over time? Is it due to change in the project or to other program or policy changes in your district? [**context**]

3. What has been your involvement with project? (*e.g. encouraging teachers to participate, participating yourself, observing, scheduling, project planning or management)* [**interim outcomes/F3**]

4. Have you worked with university math and science faculty in this project? Are they different from other professional development providers who have worked with your district? If yes, in what ways? [**interim outcomes/F3**]

5. Can you describe teachers' reactions to the project activities? *(e.g. attitudes, level of satisfaction)* [**interim outcomes/F3**]

6. What is your assessment of the collaboration with math and science faculty and district teachers so far? [**interim outcomes/F3**]

7. Do you think the project has improved teacher content knowledge, pedagogical skills and professional attitude in your school? What is the contribution of STEM faculty? Can you provide some examples? [**interim outcomes/F3**]

8. Do you think the project has improved student achievement? What is the contribution of STEM faculty? Can you provide data or give some examples? [**interim outcomes/F3**]

9. Has there been any impact of the project at the district level? [**interim outcomes/F3**]

10. Do you think the collaboration with STEM faculty can be sustained after the project is completed? What would be needed to enhance the sustainability? [**long-term outcomes/F4**]

11. Are there other things you'd like to discuss about STEM faculty participation or its results?

CLASSROOM OBSERVATION PROTOCOL (K–12 CLASS, INSERV PD, PRESERV CLASS)

Presenter: MSP:

Observer: Location:

Date: Duration:

Background *(Check all apply)*

1. Number of participants

   ☐ 1-10 ☐ 11-25 ☐ 26-50 ☐ 51 or more

2. Types of participants

   ☐ K–12 teachers ☐ K–12 students ☐ preservice candidates

3. Subject

   ☐ math ☐ science

4. Grade level

   ☐ elementary ☐ middle school ☐ high school ☐ undergraduate ☐ graduate

5. Session focus

   ☐ content ☐ pedagogy ☐ instructional materials ☐ Other *(specify)* __________________

6. Main activities and teaching techniques

   ☐ formal presentation/lecture ☐ collaborative learning

   ☐ class reports ☐ small group work

   ☐ inquiry-based ☐ problem-based learning

Comments

7. What was the specific STEM content of the lesson?

8. To what extent and how effectively did the instructor

   - Present the material in a clear fashion?
   - Encourage participants to generate ideas and questions?
   - (*Preserivce only)* Provide opportunities for participants to consider classroom applications?

9. Were participants intellectually engaged? In what ways?

10. Please provide brief comments about other noticeable features.

11. What is your overall impression of the session?