The Merck Institute for Science Education: A Successful Intermediary for Education Reform

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Biography

Tom Corcoran is co-director of the Consortium for Policy Research in Education (CPRE). Prior to joining CPRE, Corcoran served as the education policy advisor for New Jersey Governor James Florio, director of school improvement at Research for Better Schools, and director of evaluation and later chief-of-staff of the New Jersey Department of Education. His research interests include the use of research to inform policy and practice in public education, the efficacy of different approaches to professional development, the effectiveness of whole-school reform, the impact of changes in work environments on the productivity of teachers and students, and the factors affecting the effectiveness of scaling-up strategies.

About MISE

In 1993, Merck & Co., Inc. began an endeavor to make a significant and visible commitment to improving science education by creating the Merck Institute for Science Education (MISE) and supported the new venture with a 10-year, $20-million financial commitment. From its inception, MISE had two goals: to raise the interest, participation, and performance of public school students in science, and to demonstrate to other businesses that direct, focused involvement would hasten the improvement of science teaching and learning in the public schools. MISE initiated its work by forming partnerships with four public school districts — Linden, Rahway, and Readington Township in New Jersey, and North Penn in Pennsylvania —where Merck had major facilities. To learn more about MISE, visit www.mise.org.

CPRE's Evaluation of MISE

CPRE, based at the University of Pennsylvania, was contracted by MISE in 1993 to document the implementation of the initiative and assess its impact on districts, schools, classrooms, and students. Throughout the evaluation, CPRE conducted interviews with teachers, instructional leaders, and district personnel; surveyed teachers; developed case studies of schools; and examined student achievement data in order to provide feedback on the progress of the MISE Partnership.

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The Evolution of the Merck Institute for Science Education

Year	Primary Focus	Major Accomplishments
1992-1993	Launching the initiative	Merck & Co., Inc. created the Merck Institute for Science Education (MISE) with a 10-year, $20-million commitment and the goal of raising student interest, participation, and performance in science.
1993-1994	Building awareness and providing assistance, and setting the groundwork for use of nationally developed curriculum materials	The newly created MISE focused on cultivating relationships with its four partner districts, three in New Jersey and one in Pennsylvania. MISE assisted districts with selection and purchase of new materials for elementary science; and helped local educators envision a new approach to science education by sponsoring their attendance at national conferences, exposing them to state-of-the-art materials and national resources, and encouraging them to visit classrooms with standards-based science instruction. MISE created resource center enabling educators to review and try out new instructional materials.
1994-1995	Taking a more proactive role, evolving into a single Partnership, and designing and implementing the Leader Teacher Institute	MISE focused on improving the quality and accessibility of professional development for teachers. MISE staff assumed a more proactive leadership role and, in the summer of 1995, implemented the Leader Teacher Institute, enrolling more than 140 teachers. This offered a common professional development experience for teams of teachers in the four districts. This helped create a single Partnership -- MISE and the four districts.
1995-1996	Increasing resources through a National Science Foundation grant, implementing the Peer Teacher Workshops, continuing the Leader Teacher Institute, and focusing on local policy alignment	MISE received a National Science Foundation Local Systemic Change grant for the purpose of providing 100 hours of high-quality professional development in science and math to 800 K-8 teachers from the four districts over five years. The second year of the Leader Teacher Institute was held. Peer Teacher Workshops were implemented and more than 160 teachers participated in the first summer. As Leader Teacher teams assumed more professional development roles, MISE staff evolved from a supplier of professional development to a facilitator of schoolwide instructional change.
1996-1997	Continuing the Peer Teacher Workshops, completing the Leader Teacher Institute, and focusing on curriculum frameworks and assessment	Two hundred teachers took part in the Peer Teacher Workshops, which were partially led by Leader Teachers. The final year of the Leader Teacher Institute was held. MISE gave more attention to mathematics. The MISE Resource Center was expanded to include material for elementary and middle school math. All four districts completed draft science curriculum frameworks aligned with state and national standards.
1997-1998	Increasing district responsibility for professional development, expanding assessment work, initiating comprehensive planning, and continuing work with Leader Teachers	The Partnership had evolved into a broad collaboration. Peer Teacher Workshops were expanded with 138 teachers participating. Communication and leadership skills of Leader Teachers were expanded to support them as advocates, coaches, and instructors in their schools. MISE staff worked to gain board approval for district curriculum frameworks. Work on improving student achievement measures started.

Year	Primary Focus	Major Accomplishments
1998-1999	Expanding professional development offerings, strategic planning in science, developing a Partnership Assessment Plan, sharing the work of the Partnership, influencing New Jersey policy	MISE increased professional development offerings in the summer of 1999 and helped districts organize and deliver 36 Peer Teacher Workshops, thus building internal district capacity. MISE staff worked with district teams to develop strategic plans that focused on curriculum and instruction, student achievement and participation, policies and practices, and parent and community support. The Partnership adopted an action plan for student assessment in science. MISE staff expanded outreach efforts with new publications that outlined their vision and work. An assessment sampler for teachers was developed. MISE staff provided leadership to statewide boards and committees developing science content standards and professional teaching standards.
1999-2000	Continuing the Peer Teacher Workshops, expanding and focusing the work in the middle schools, implementing the Partnership's assessment plan	MISE and the districts offered 31 Peer Teacher Workshops in science and math in the summer of 2000, held in district locations to increase participation. MISE staff expanded and strengthened work in middle schools. Teams of teachers and MISE staff selected, modified, and tested two TIMSS (Third International Mathematics and Science Study) tasks for third and seventh grades.
2000-2001	Expanding the district role in the design and delivery of the Peer Teacher Workshops, implementing the Principal's Institute, working on site in three middle schools, and working on the Performance Assessment project	MISE continued to offer Peer Teacher Workshops. A two-day institute for school principals was held to increase their understanding of high-quality science instruction and their capacity to help teachers provide it. MISE staff continued to work on the development of curriculum frameworks and the selection of instructional materials for the middle grade level. The Partnership Performance Assessment project was replicated in all grade 3 and 7 classrooms.
2001-2002	Continuing the enhancement of local district responsibilities for Peer Teacher Workshops, implementing the Principal's Institute, working on site in three middle schools, initiating work at one partner high school, and enhancing the Performance Assessment project	Peer Teacher Workshops reflected the needs of a context where there is a high level of district commitment to standards-based science. A two-day conference continued the institute for principals to focus on their roles in encouraging good science teaching through teacher observations. MISE staff worked with district committees to establish formal curriculum frameworks for school board adoption. Science reform work was initiated at one partner high school using the selection of instructional materials as the reform focus. The Partnership Performance Assessment project was expanded with tasks administered at grades 3, 7, and 8.
2002-2003	Continuing Peer Teacher Workshops, continuing the Principal's Institute, working on site with middle schools, implementing science reform work at one partner high school, and initiating district-level assessments for science modules	Peer Teacher Workshops responded to the needs of districts committed to standards-based science. A second conference for principals focused on the power of professional dialogue about instruction. Science reform work continued at one partner high school using the selection of instructional materials as the reform focus. Two partner districts cooperated to develop, administer, and interpret summative assessments aligned with instructional modules.

Introduction

A variety of technical assistance organizations have been created in the last 20 years to help public schools implement reforms to improve their performance. These organizations vary in size, sponsorship, and focus, but their creation rests on the common premise that the reforms needed in the schools to educate all children to high standards require strong external stimuli and resources and knowledge beyond what are ordinarily available in public school systems (McDonald, McLaughlin, & Corcoran, 2000). Accordingly, these technical assistance organizations forge partnerships with school systems under pressure to improve their performance. Working across the boundaries of the educational system, these organizations serve as catalysts for reform, offering schools and districts expertise and other resources needed to make the desired changes. Dedicated to the implementation of reforms, they are presumed to be free of the ordinary interests and ordinary political pressures and, therefore, more likely to be able to overcome the inertia and resistance that often block reform in public bureaucracies like school systems.

Researchers have not paid sufficient attention to these organizations, yet they play an increasingly important role in the improvement of public education. To stimulate more interest in these organizations, and in understanding what makes them effective, we report here on the Merck Institute for Science Education (MISE). For nearly 10 years, the Consortium for Policy Research in Education (CPRE) has evaluated MISE's partnership with four school districts in New Jersey and Pennsylvania, providing MISE staff with feedback on the progress of their work and assessing MISE's impact on schools, teachers, and students. This long-term relationship has provided an extraordinary opportunity for both CPRE and MISE staff to gain insights into how a technical assistance organization works with school districts to change classroom practice. The story of MISE, and its efforts to bring about instructional reforms in science, is a story of vision, collaboration, learning, and persistence. It is also a success story that offers important lessons for other intermediary organizations working with school districts to improve teaching and learning.

Origins of MISE

Merck & Co., Inc., the third largest pharmaceutical company in the world in terms of revenues (College Journal, n.d.), has a long history of supporting public education. Before school-business partnerships became popular, Merck was contributing grants, gifts, and the time and talents of its employees to the improvement of science education in public schools and higher education. However, Merck executives were not entirely satisfied with these efforts to assist the public schools. They knew that although their gifts were appreciated by the communities that received them, their impact on teaching and learning in the public schools was limited. They were also concerned about the declining supply of well-trained scientists and technicians in the United States and felt that steps had to be taken to increase the interest of American students in science. And as a pharmaceutical company, they also recognized that new developments in science, such as biotechnology, required a higher level of scientific literacy in the general population.

After participating in a national education summit convened by President Bush and the nation's governors in 1991, at which national goals for the improvement of education in the United States were established for the first time, Merck executives felt that the corporation should make a significant and visible commitment to improving science educa-

The Study of MISE

Since 1993, CPRE has been documenting MISE's work in the four partner districts, and providing MISE with feedback on the implementation of its strategies and their impact. Between 1993 and 2002, CPRE regularly interviewed school and district staff, observed science classrooms, surveyed teachers, developed case studies of schools, examined student achievement data, and conducted special analyses to answer questions of concern to MISE and the districts. The long-term character of this research and the breadth of the data set provide a unique look at the development and impact of a technical assistance organization. This work is reported in eight annual reports, published between 1994 and 2002, which are available from CPRE.

tion. Although becoming first in the world in mathematics and science by the year 2000 seemed unrealistic, they believed significant progress was possible with a more focused and hands-on approach. In 1993, Merck created the Merck Institute for Science Education and supported the new venture with a 10-year, $20-million financial commitment. From its inception, MISE had two goals: to raise the interest, participation, and performance of public school students in science, and to demonstrate to other businesses that direct, focused involvement would hasten the improvement of science teaching and learning in the public schools.

MISE quickly formed partnerships with four school districts in which Merck facilities were located and where area residents were familiar with a Merck presence in their schools. Three of these districts were in New Jersey — Linden, Rahway, and Readington Township — and the fourth was the North Penn School District in Pennsylvania.

MISE invited leadership teams from each district — including the district superintendent, the science and/or mathematics supervisor, school principals, and Leader Teachers — to serve on a district advisory committee and to provide input on critical decisions affecting its work. Over time, this advisory committee developed into a learning community that shared a common reform agenda, and the individual partnerships between MISE and the four school districts evolved into one unified Partnership. This enabled MISE and the four districts to work collaboratively as one entity, united in purpose and goals.

Taxpayers and parents in the four districts were delighted to have their school systems form partnerships with a corporate neighbor whose expertise in science was respected and whose largesse had been bestowed on their schools in the past. This time, however, the relationship would be different, not only because of the increased investment by Merck, but also because the new activist strategy represented by MISE sought greater commitments from the school districts; changes in district policies, culture, and organization; and specific reforms in curriculum and instruction.

A New Vision for Science Education

Guided by a board of advisors that included representatives of the National Science Resources Center, the National Science Teachers Association, the National Academy of Sciences, and leading scientists and science educators, and led by a respected science educator, a small MISE staff set out to reform science teaching in the elementary and middle grades in the four school districts. They sought a dramatic transformation from textbook-based, memorization-oriented instruction to guided inquiry in which students actively engaged in science

investigations based on structured curriculum units such as those developed by FOSS (Full Option Science System) and STC (Science and Technology for Children). While some reformers subscribe to a more radical view of inquiry in which students determine what topics and questions they wish to explore and design and conduct their own inquiries, MISE offered a more practical vision suited to K-8 teachers. Their goals were to persuade districts to adopt well-designed, commercially available science modules that would support inquiry or investigations guided by teachers and cover the key concepts identified in state and national standards, and to help districts prepare teachers to use these instructional materials both effectively and consistently.

While supportive of student inquiry, MISE staff recognized that teachers and schools needed a more structured approach to be successful. This strategy was termed inquiry-centered science teaching. MISE wanted inquiry-centered teaching to be the norm in science classrooms, an integral and regular part of the experience of all students at all grade levels. In these classrooms, students would be developing and exploring scientifically oriented questions, giving priority to evidence, and formulating, evaluating, and communicating their explanations. This vision of high-quality science education was new to many administrators and teachers in the partner districts. And moving elementary science teaching away from a heavy dependence on textbooks and toward inquiry posed significant challenges. As in most school districts across the United States, science was being taught by generalist teachers whose science backgrounds were often minimal — typically consisting of only one or two basic college courses. In fact, making sure science was taught at all in the elementary grades was an issue. There were no state assessments in science when the MISE staff began their work, and the reputations of elementary schools and their relationships with the state departments in New Jersey and Pennsylvania depended on the performance of students in reading, writing, and mathematics, not science. Thus, in many elementary classrooms, little attention was given to science, and when it was taught, it was often merely an extension of the reading program.

To put this new vision of science teaching into practice, the MISE staff realized that they would have to do more than provide professional development for teachers. Their strategy was systemic and was based on studies of previous efforts to improve teaching (Corcoran & Goertz, 1995; Goertz, Floden, & O'Day, 1995). The theory included the following nine components:

- Persuading districts to make the improvement of science teaching a priority, and to engage in serious planning to address it;
- Developing a leadership team in the district that shared a common vision of science teaching grounded in inquiry and consistent with state and national standards;
- Helping districts develop new curriculum frameworks for science, select appropriate instructional materials, and develop systems for the management of the materials to ensure they could be used effectively;
- Supporting the use of assessments that were consistent with the vision of good teaching, including formative assessments, end-of-unit assessments, and district-wide performance assessments and examinations;
- Building district capacity to plan and deliver professional development that prepared teachers to use the materials effectively;

- Developing district and school instructional leaders to carry out this work;

- Developing professional cultures for the districts and schools that would promote continuous improvement of science teaching and develop teacher expertise;

- Aligning district policies for curriculum, professional development, resource allocation, and teacher evaluation with the vision of reformed practice and the strategies for improvement; and

- Promoting supportive state policies.

The leaders of MISE felt that only such a systemic approach could stimulate, support, and sustain the reforms in classroom practice that they sought. They realized that new curriculum materials and professional development would be needed, but they also recognized that school and district policies governing curriculum, assessment, professional development, resource allocation, personnel evaluation, and accountability would have to be aligned with the new vision of high-quality science teaching.

For nearly a decade, MISE has pursued this vision and CPRE has been documenting their work and its impact. What follows is the story of MISE, and the lessons that have been learned from its efforts to improve science teaching.

Learning from Experience

The story of MISE can be divided roughly into four phases reflecting the elaboration of MISE's approach to reform. In each phase, MISE altered its strategies as a result of feedback from its partners and CPRE, changes in the policy environment, and new funding opportunities.

Phase 1: Developing a Shared Vision

In 1993, neither MISE's partner districts nor the two states (New Jersey and Pennsylvania) had content standards or assessments in science. District curriculum guidelines for science were often vague and often ignored. Most teachers lacked the materials and equipment necessary to engage in inquiry. Instructional expenditures for science materials were low. Shaped by teacher interests and accountability demands on the schools, science instruction was often little more than an extension of the reading curriculum. In some classrooms, children explored central concepts in science, but in many others, they did little more than read about nature. This was the condition of science education that MISE, in partnership with the districts, set out to change.

In the first two years, MISE staff set out to build a shared vision of good science teaching with the partner districts. They cultivated relationships of trust with each district by engaging district superintendents, central office staff, principals, and teacher leaders in open discussions about the science standards, the quality of the existing science curriculum, and their expectations for their students. They convinced the districts to re-examine and revise their K-8 science curricula. Leadership teams from each district went to the National Science Resources Center's Elementary Science Leadership institutes with technical and financial support from MISE. Each attending team worked on a five-year strategic plan for reforming science education in their system. The institutes focused on the selection of inquiry-centered sequential science curriculum units, professional development to prepare teachers to use inquiry-centered teaching methods, cost-effective support systems for supplying science

materials and apparatus to classrooms, assessment methods consistent with inquiry-centered science, and strategies for building administrative and community support. Upon their return, MISE staff worked with them to review the science modules that were available for elementary- and middle-grade science, and assess their suitability for inquiry teaching. Through this process, a shared vision of inquiry-centered science teaching emerged.

Rather than adopting new curricula all at once, MISE encouraged the districts to select high-quality science modules for each grade as the foundation of their elementary science curricula and to phase them in gradually so as not to overwhelm teachers. The modules selected by the districts fit the shared vision of inquiry teaching. To support this process, MISE opened a resource center that loaned out instructional materials so that district staff could examine those that fit what they were trying to do in the classroom. This allowed local teachers to test out the new science modules in local schools prior to their purchase and adoption. Once districts selected appropriate materials, MISE funded the purchase of these new curricular modules which became the foundation of a more rigorous, standards-based elementary science curriculum in each of the partner districts. In addition, MISE encouraged partner districts to examine their personnel policies and procedures to ensure they were recruiting and hiring qualified teachers and to develop strategic plans that would incorporate the instructional reforms sought by the Partnership. In the first two or three years of the Partnership, all four districts made major changes in their elementary science curriculum.

Phase 2: Building Cultures of Instructional Improvement

The adoption of new instructional materials in the elementary schools quickly generated requests from teachers for more and better professional development and on-site support. Teachers needed better understanding of the subject matter addressed by the new curriculum materials so they could encourage students to ask critical questions and help them seek meaningful answers. They also needed to understand how to organize opportunities for inquiry, how to set up their classrooms, and how to replenish supplies for and manage the new science modules. Building supports for instructional change became the focus of the next few years as MISE continued to support the adoption of the new curriculum materials.

With the assistance of the partner districts, MISE designed and implemented a new program to prepare Leader Teachers in each school to support the use of the new curriculum and the use of inquiry in the classroom. Between 1995 and 1998, the partners designed and implemented a voluntary three-year professional development experience for teams of teachers selected from each elementary and middle school in the four partner districts. This Leader Teacher Institute (LTI) provided three-week summer institutes and academic-year sessions focused on a different domain of science (biological, physical, and earth sciences) each year intended to deepen teachers' content knowledge, sharpen their teaching skills, and prepare them to serve as mentors, coaches, and advocates. The creation of the LTI had an important impact on the partnerships themselves. By recruiting more than 140 teachers from all four districts into a common professional development experience, the four separate partnerships became one unified Partnership. The LTI required significant

commitment from MISE, the districts, and the teachers, and these commitments forged a bond that would prove lasting.

Impact on Teaching Practices. The Leader Teachers received nearly 500 hours of professional development over three years, and observations of their practice by CPRE researchers found that their teaching changed dramatically by the third year and was considerably above average on a National Science Foundation (NSF) observation classroom instrument. Survey data also showed significant changes in their practice. By the third year, all of the Leader Teachers had made significant changes in their practice and the vast majority were engaging students in inquiry on a regular basis. After three years of involvement, however, their practice began to stabilize as they encountered the time limits faced by all elementary teachers who teach multiple subjects and pressures to attend more to reading and mathematics.

Spreading Reformed Practice. The goal of the LTI was to increase the internal capacity of each school in the partner districts to support change in instructional practice. The Leader Teachers were expected to serve as advocates of inquiry-centered instruction, and to coach other teachers in these methods. Many of them conducted professional development for their peers, and some went into classrooms to observe and coach. After two years, however, it was clear that the impact of this change strategy was uneven. Some Leader Teachers were successfully engaging their colleagues but others encountered serious obstacles, such as their own credibility as science teachers, time constraints, peer resentment, and lack of principal support. (Detailed accounts of the strategies used by Leader Teachers and the obstacles they encountered can be found in CPRE, 1999, pp. 56-63, and CPRE, 2000, pp. 59-64).

The lessons from the LTI initiative were not lost on MISE. Successful diffusion of reformed practice in the schools clearly depended on which individuals were selected to be Leader Teachers; the individuals not only had to have interest in, and knowledge of, science but they also had to be respected by other teachers in the school and have good relationships with their colleagues. The LTI selection process had not always resulted in the recruitment of those with the most potential for effectiveness. And once selected, the Leader Teachers had to have the support of principals. To succeed in reaching their peers, they also needed released time that districts and principals, facing demands to improve reading and mathematics, sometimes would not provide. Given these obstacles and the prevailing norms of high teacher autonomy and classroom privacy, spreading inquiry through the Leader Teachers required a cultural revolution in each school that was difficult to spark.

But the LTI experience offered another powerful lesson for MISE and its partner districts. Intensive professional development had altered the practice of the Leader Teachers, and the Leader Teachers felt that similar opportunities would encourage their fellow classroom teachers to adopt the inquiry method and help them use the new curriculum materials effectively. Although MISE all along had been encouraging district efforts to provide all elementary teachers with more professional development in science, the announcement of the Local Systemic Change program by NSF provided the Partnership with the opportunity to expand and intensify these learning opportunities.

Phase 3: Broadening Access to Professional Development

In 1995, the Partnership received a five-year Local Systemic Change grant from NSF to provide more teachers with

Table 1. Peer Teacher Workshops, 1996-2001

Year	Number of PTWs	Math PTWs	Math and Science PTWs	Science PTWs	PTW Enrollment	Number of Individuals
Summer 1996	6	0	0	6	169	169
Summer 1997	8	2	0	6	195	195
Summer 1998	22	8	1	13	506	287
Summer 1999	36	9	1	26	525	386
Summer 2000	32	9	2	21	667	490
Summer 2001	37	12	1	24	536*	394*
Total	141	40	5	96	2,598	1,921

** Includes estimated enrollments in locally sponsored math PTWs.*

Source: CPRE (2002, p. 19)

direct access to curriculum-related professional development in both science and mathematics. The centerpiece of this project was a new professional development strategy, the Peer Teacher Workshop (PTW), that would make intensive professional development available to all teachers. Each week-long PTW was based on one of the curriculum modules used in the districts, and was designed to deepen teachers' understanding of the science in the module, their appreciation of common student misunderstandings of the key concepts, and their ability to use inquiry. The encouragement of teachers to attend as grade-level teams, the organization of follow-up sessions during the school year, and support from district resource staff meant that the PTWs were also excellent vehicles for building and strengthening professional learning communities in the schools that could carry and deepen the vision of inquiry-based science. The goal was to provide at least 80% of the 800 teachers who taught math and science in grades K-8 in the four partner districts with 100 hours of this kind of professional development over a five-year period.

The PTWs were designed by instructional teams comprised of accomplished teachers from the partner districts and content experts drawn from MISE staff, high schools, universities, and curriculum development organizations. The new strategy utilized the local capacity developed through the LTI by recruiting successful Leader Teachers to help design and deliver the PTWs. The three-to-four person instructional teams were selected by MISE and district staff and supported by an annual three-day design retreat held in the spring several months before the workshops. At these annual retreats, MISE staff and other experts helped the instructional teams design workshops that modeled inquiry, taught the participants the underlying science or mathematics, and prepared them to manage the curriculum unit.

Table 1 displays the number, types, and enrollment of Peer Teacher Workshops held since 1996. These data show steady growth in participation from 1996 to 2000 and then a leveling off at a relatively high level of participation. During 1999, 2000, and 2001, approximately half of the nearly 800 K-8 teachers teaching

science and/or mathematics in the four districts participated in PTWs. By 2002, over 80% had participated which, given the other demands on teachers' time during this period, especially the strong emphasis placed on reading, was a significant accomplishment.

Improving Participation

This high rate of participation was not so easily achieved. After the PTWs had been in place for three years, approximately 40% of the teachers in the districts still had not participated. While observing and interviewing teachers in the Partnership districts, CPRE noted that teachers who had not yet participated in Partnership professional development were often quite knowledgeable about MISE's involvement in their district and some described the Partnership in glowing terms. CPRE initiated a study of these non-participants and interviewed a stratified (by grade level) random sample of approximately 10% of the teachers who had not yet participated in the Partnership's professional development.

Survey data revealed no differences between participants and non-participants in terms of experience. Teachers with over 20 years of experience were equally as likely to participate in the PTWs as their younger or less-experienced peers. Furthermore, participants did not have stronger backgrounds in science. Differences between participants and non-participants were found in three crucial areas: their enjoyment of teaching science, their preparation to teach it, and their conceptions of professional development. Not surprisingly, participants reported greater enjoyment of teaching science and being better prepared to teach it. Not much could be done about these attitudinal differences unless non-participants could be persuaded to attend the PTWs.

The information about non-participants' conceptions of effective and desirable professional development was more useful. Their perceptions collided with the design of the PTWs in four important ways, described more fully below. First, the length of the PTW clashed with their expectations. Second, the professional development strategies were inconsistent with non-participants' preferences. Third, the content of the professional development was not a priority for them. Fourth, the timing and location of the PTWs were barriers to participation. Thus, the structure, style, content, and logistics of the PTWs were perceived to be barriers to participation.

Non-participating teachers overwhelmingly preferred short professional development experiences. Most of those interviewed said that committing a full week to professional development was *extremely* unattractive. They preferred one-day events that they could attend on professional release days provided by their districts. They were hesitant to commit more of their time outside of the school day to professional development.

Non-participants also conceived of effective professional development as the dissemination of information, rather than more active exploration of larger ideas and concepts based on subject-content knowledge. These views conflicted with the philosophy behind the Partnership's professional development. When asked to describe the most effective structure of professional development, these teachers overwhelmingly preferred one-day workshops where they *received* materials and were *led* by an interesting instructor. Furthermore, the PTWs made the practice of many of the participants more public. It is important to recognize that the traditional culture of teaching is insulated; one's struggles and shortcomings are often kept behind closed classroom doors. Despite the supportive, reflective nature of these workshops, these teachers

were less willing to open their practices to their peers, and therefore they were less willing to attend the workshops.

The content of the PTWs also conflicted with non-participants' preferences. Most of the elementary teachers interviewed preferred professional development in the language arts rather than in science or math. Furthermore, the teachers interviewed were more likely to choose general areas for professional development than opportunities to deepen their content knowledge in any one area. Finally, offering the PTWs in the middle of the summer in locations that were some distance from teachers' homes also deterred the non-participants. They preferred professional development during the school year or immediately following the school year and preferred it to be offered in their districts.

In response to these findings, the Partnership made changes to the structure and marketing of its summer workshops. The expanded offerings included some choices not directly tied to specific science curriculum units, such as using technology in the science classroom, assessment, and integrating science and language arts. These choices may have attracted teachers who preferred more general areas for professional development, who traditionally sought language arts workshops, or who needed to learn more about technology. Informal networks of participating teachers also recruited their peers. The Leader Teachers were strongly encouraged to attend. In response to district requests, the Partnership changed the timing of the workshops so they occurred immediately following the close of the school year. Also, one district was able to offer teachers the option of graduate credit. These efforts led to the recruitment during the following summer of 34% of those who had previously not participated, and eventually two-thirds of those who had not participated in the first three years (CPRE, 2000).

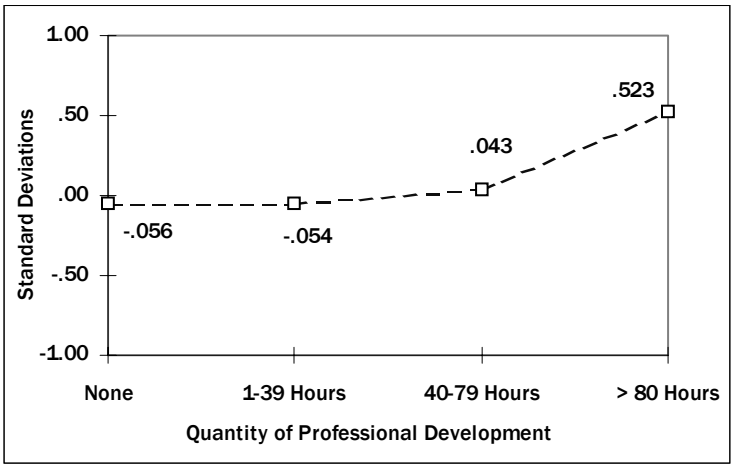
Impact on Practice

To analyze the impact of this professional development on teaching practice as reported by teachers, CPRE evaluators examined the statistical relationship between reform-based teaching practice and Partnership-provided professional development while controlling for certain teacher background and school characteristics (CPRE, 1999). Hierarchical linear modeling, a sophisticated form of regression analysis that takes into account that classrooms are nested within schools, was used (Bryk & Raudenbush, 1992).

Using data collected from surveys of teachers and principals in the four partner districts, CPRE evaluators aggregated a series of survey items about teaching practices in science. The survey items asked teachers how frequently they used certain practices, such as requiring students to supply evidence to support their claims, demonstrating a science-related principle or phenomenon, and using assessment to find what students know before or during a curriculum unit. Teacher content familiarity, teaching experience, and amount of professional development were used as independent variables to predict teaching practice. At the teacher level, the sample consisted of 334 teachers. Twenty-eight percent of these teachers reported they had received no science-related professional development during the year prior to the study, 33% reported receiving between 1 and 39 hours, 17% reported receiving between 40 and 79 hours, and 22% reported receiving 80 or more hours.

The most striking result from this model of science teaching is the statistically strong relationship between high levels of quality professional development and reform-based teaching practice. After adjusting for differences in teachers' content background, teaching experience, and school environment, teachers with more than 79 hours of professional

Figure 1. Impact of Professional Development on Teacher-reported Science Teaching Practice



development used significantly more reform-based teaching practices than did teachers with fewer than 79 hours of professional development. Figure 1 depicts the relationship between teaching practice and professional development.

Teachers who had either no professional development or between 1 and 39 hours of professional development had approximately average teaching practice (that is, their scores on the scales developed from the survey items were at about the mean). Teachers who had between 40 and 79 hours of professional development were slightly above average in terms of their use of reform-based teaching practice. Teachers who received 80 or more hours of professional development were much more likely to have altered their practice.

Also notable was the relationship between content familiarity and reform-based teaching practice. Each additional semester of college science (a proxy for content familiarity) was associated with a statistically significant .11 of a standard deviation increase in the model's measure of reform-based teaching practice. This suggests that content-based professional development is important and bears further investigation. There was no significant relationship between years of teaching experience and reform-based practice. This finding casts doubt on the widespread assumption that experienced teachers are more reluctant to change their practice than relatively new teachers.

Finally, direct observations of classroom practice by CPRE researchers in 1998, 1999, and 2000 found both the Leader Teachers who had received intensive professional development in the second phase of MISE's work and the teachers who had attended the PTWs had changed their practice, and both were using the science modules to engage students in guided inquiry. Using an observation instrument developed by Horizon Research for the NSF Local Systemic Change evaluation, CPRE researchers found the Leader Teachers to be somewhat more advanced in their use of inquiry, but both groups were above average on the NSF scale, and the observed differences between them were narrowing each year (CPRE, 1999, pp. 34-36).

Phase 4: Sustaining the Work

The Local Systemic Change grant ended in 2001, but the four districts, with modest support from MISE, have continued to offer the PTWs. In the summer of 2002, 25 PTWs were offered by the four districts. Moreover, the general design of the PTWs has been extended to other subject areas in all four districts. Each of the districts now has a cadre of teachers who have designed and led PTWs in science and mathematics. They have the capacity to offer teachers high-quality professional development. These experienced leaders also serve as coaches and mentors in their schools, and as curriculum leaders in their districts. The experience serving on an instructional team gives them the knowledge, skills, and credibility to be leaders in other ways. Equally important, these experiences have raised the standards for professional development. Teachers in these districts expect well-designed practical experiences that enable them to do a better job with the curriculum that they must teach.

MISE has continued its work in a number of noteworthy ways. For example, the Partnership offered a two-day institute for principals to enhance their understanding of high-quality science instruction and their capacity to help teachers provide it. Organized by principals from the four partner districts and MISE and CPRE staff, the institute was attended by 41 principals and a number of central office staff. MISE staff also worked with districts on the development of curriculum frameworks and selection of instructional materials for middle school science. MISE continues to support and develop the work of the four partner districts and is expanding the Partnership to include other school districts.

MISE's Approach to Professional Development

While MISE modified its approach to professional development as a result of experience and CPRE's evaluation, the core principles guiding its design were constant. According to these guiding principles, professional development should be:

- Based on a clear vision of good practice;
- Linked to specific curriculum units and focused on the content teachers must teach;
- Carefully designed and planned to provide knowledge and skills that were immediately useful in the classrooms of the participants;
- Respectful of teachers and based on a coherent theory of adult learning;
- Intensive but also extended over time through on-site support to allow for practice and reflection;
- Led by accomplished teachers who modeled good instructional practice and collaborative work;
- Easily accessible for all eligible teachers; and
- Sustainable over time by local districts.

These principles are consistent with the prevailing consensus on effective professional development (Corcoran, 1995; Elmore, 2002; Sparks & Hirsh, 1997).

MISE's use of the priorities of districts and schools to guide professional development differs from much current practice which permits individual teachers to

choose their own learning opportunities. MISE's goal is to build a shared vision about sound instruction and communities of practice that can work together to enact it. While teacher participation in PTWs is voluntary, there are strong incentives for teachers to participate including peer pressure and stipends. Because there are no linkages between participation or performance in the PTWs and personnel evaluations, PTWs are seldom seen as high-stakes or threatening experiences. From the start, MISE sought to build district capacity to provide high-quality professional development on a sustained basis. Gradually, the responsibility for training has shifted to the partner districts where teachers and others trained through the PTWs are leading the work.

Strengthening Content Knowledge

As noted earlier, building teacher content knowledge in science has been a major focus of the Partnership's professional development program. Needs of teachers were assessed through surveys, examination of student assessment results, and discussions with supervisors and principals. Most of the content experts used in the PTWs were skillful in addressing the content needs of participants, linking activities and instructional ideas to the "big ideas" in the curriculum modules. Workshop participants reviewed curriculum content and discussed problems that students were having with it. While CPRE researchers are persuaded that most PTW participants learned a great deal of new science content, there is only limited empirical evidence to support this claim. CPRE's conclusion is based on observations of content discussions in the PTWs, the amount of time devoted to such discussions, the attention given to content in the workshop materials, and teacher self-reports about what they learned.

The Systemic Context

It is important to remember that this professional development was the centerpiece of a broader reform effort, and that MISE's approach was systemic. They intentionally set out to alter the environment in which teachers were working. In addition to helping the partner districts select new science curricula, MISE helped them develop new curriculum frameworks. Through the process of selecting materials and designing professional development, MISE had a profound effect on the norms of good practice in science teaching and the expectations of teachers held by central office curriculum staff. These new norms were also shared with principals through a series of institutes at which principals observed, rated, and discussed videos of science teaching. These other activities created environments which were supportive of the professional development.

The Impact of MISE's Work

The Partnership formed by MISE and the four school districts can point to some real accomplishments. Clearly, the science curriculum in the four partner districts has been strengthened and science has become a core subject in the elementary schools. MISE and district staffs have worked together to develop curriculum frameworks aligned to state and national standards, selected appropriate instructional materials, and designed and developed professional development activities that support the new curricula. The once fragmented, textbook-driven, and uncertain science curriculum has been replaced by well-structured curricula incorporating well-designed science modules focused on important concepts linked to the state standards. Teachers have access to science modules and materials that were not available 10 years ago and, most

importantly, they are expected to use them. Students in the partner districts are now assured of exposure to a well-balanced, inquiry-centered science curriculum.

Students also are assured of a better and more equitable opportunity to learn science because science instruction has also improved. Many teachers have a deeper understanding of the content and have adopted inquiry approaches as a result of the intensive professional development offered by the Partnership and support from teacher leaders and supervisors. Using NSF-developed observation tools that focus on the use of inquiry, CPRE has found the vast majority of elementary teachers in the Partnership schools to be using inquiry as a primary method for teaching science.

District policies have also changed. The most obvious changes are the new curriculum frameworks, increased expenditures for instructional materials, observation procedures, and the acceptance of MISE's principles of professional development. When the NSF grant ended and the amount of external funding was reduced in the summer of 2001, the districts continued to offer PTWs and still do so. They do so because there is both a need (new teachers, new modules, and a continued desire to do it better) and a demand (teachers want the kind of professional development provided through the PTWs). An unexpected by-product has been the use of the same professional development principles to support curriculum revision innovations in literacy, mathematics, and social studies.

Other more subtle cultural changes have also occurred in the partner districts. There is more respect for, and greater use of, teacher expertise. Classroom teachers are playing leadership roles in professional development, assessment, and curriculum. Planning at the school and district levels is more collaborative and taken more seriously. There is a greater focus on results. Instructional resources have been reallocated to provide teachers with more professional development opportunities and access to exemplary K-8 science education materials at MISE's resource centers. The resources devoted to professional development are seen as investments that should be carefully designed and are expected to produce results.

Measuring Student Performance: Partial Answers and Continuing Challenges

Have these changes improved student knowledge of science or increased the numbers of students who pursue more challenging courses in high school and college? Do students in the Partnership districts do better work in science than in other comparable districts? Do they score better on common measures of science understanding? Unfortunately, the answers to these questions are somewhat ambiguous. As will be shown below, we have some evidence that the reforms have impacted student achievement, but it is limited and the identified effects are modest.

The ambiguity of the answers to questions about the impact on students stems from the challenges the Partnership has encountered in science assessment. None of the available measures of science achievement have proved adequate to the task of measuring the effects of inquiry-centered teaching. When MISE began its work, there were no standard measures of achievement in science used in the partner districts. In 1994, MISE and CPRE recommended the adoption of the SAT-9 science assessment, but the districts, sensitive to criticism of over-testing, would only agree to using the open-response items in grades 5 and 7 and did not administer the full test. These limited

data are the only longitudinal student achievement data available for all four districts. In addition, for three of the districts, CPRE has examined four years of results (1999 to 2002) on the New Jersey Elementary School Performance Assessment (ESPA) science test administered to fourth graders, but there will be no more data from this source as the test has been eliminated as the state responds to the requirements of the No Child Left Behind Act of 2001.

SAT-9 Results

Analysis of the results on the SAT-9 open-response items administered to fifth and seventh graders have not shown a consistent pattern of district-wide improvement in the partner districts. However, studies examining changes by classrooms have found some effects. In 1999, CPRE staff examined the cumulative effects on students in grades 5, 6, and 7 of being in classrooms led by teachers with different amounts of Partnership professional development. This analysis built upon, but was slightly different than, the work of Sanders and Rivers (1996). The hypothesis was that students who had different sequences of teachers with different amounts of Partnership professional development experience would perform differently. For example, students who studied science for three consecutive years in the classrooms of Leader Teachers would perform differently, on average, on the SAT-9 than would students who had three consecutive years of teachers who had had not participated in Partnership professional development. The logic is that participating teachers would have altered their practice and would be using more powerful strategies to engage students in the study of science to help students master key concepts.

The results showed that fifth-grade students whose teachers had one or two years of Partnership professional development during the 1996-1998 period outperformed students whose teachers had no Partnership professional development in the same time period. However, there was no statistical difference between students who spent two years with teachers who participated in Partnership professional development and students who spent one year with such teachers. The seventh-grade analysis shows that students taught for two and three years by Partnership-trained teachers performed similarly statistically. These students performed better than students who spent just one year with a Partnership-trained teacher. No difference was found between seventh-grade students who had one year with a trained teacher and students who had no Partnership-trained teachers. Finally, it should be noted that these differences, while statistically significant, were substantively small (CPRE, 2002, pp. 45-49).

There have been serious problems with using the SAT-9 as a measure of effectiveness. To the teachers and students in the four districts, the SAT-9 represents additional testing (it is referred to as the "Merck test" or the "CPRE test") and, because no stakes are associated with the test, it was not always taken seriously by students or teachers.

ESPA Results

Analysis of the results of the ESPA administered in fourth grade in the three New Jersey districts have not shown significant effects. While the three MISE partner districts have ranked at or near the top of groupings of similar districts since the science test was first administered in 1999, CPRE has not been able to obtain student-level data from the New Jersey Department of Education to conduct analyses. It has also been suggested that there have been differences in the difficulty of the test from year to year. The New Jersey fourth-grade ESPA also poses other problems. Although the items are

aligned with state standards, it is not possible to determine how well they are aligned with the specific content of the science modules used by the Partnership districts in the tested grades because the state department does not release the items.

Moreover, since the stakes are quite high, all New Jersey districts are motivated to perform well. There may be little apparent difference in the results obtained on this assessment through conventional test preparation, increased time spent on science, and inquiry-based instruction. Thus, better teaching and better student work may not necessarily lead in the short-run to discernible differences in results on the ESPA.

Assessment Issues

The lack of persuasive evidence that student performance had improved presented a serious dilemma for the Partnership. On one hand, school administrators, teachers, MISE staff, and CPRE staff were in agreement that student work and student interest in, and understanding of, science had changed for the better in most Partnership schools. On the other hand, the available measures of student achievement were not recording significant gains. The consensus view was that the assessments were flawed and were not sensitive to the changes occurring in student learning. Moreover, MISE and district staff felt that the availability of better formative assessments linked to the science modules and increased use of performance assessments would contribute to further improvements in teaching.

The Assessment Plan

In response to these problems, MISE and the partner districts developed a four-part plan in 1998 to improve assessment in science. MISE convened several meetings on the topic of student assessment in science to develop a consensus on the best way to assess the effects of the instructional reforms being promoted by the Partnership. Interest in developing a more comprehensive assessment plan was driven in part by district dissatisfaction with the SAT-9 and the desire for better information. A variety of constituencies — including MISE, the four partner school districts, classroom teachers, Merck, and CPRE — shared these concerns. There was general agreement among the meeting participants on the importance of using a nationally recognized, standardized measure. However, the participants also wanted to collect assessment information more closely linked to the module-based curriculum used in the districts. They wanted performance information that could be standardized and aggregated across schools and that was reliable enough to provide the basis for programmatic conclusions.

These conversations culminated in development of a four-component Partnership assessment plan. The four components were:

1. A nationally recognized, standardized test consisting of multiple-choice and/or open-ended items focusing on central themes in science;

2. A set of tasks consisting of performance, multiple-choice, or open-ended items more closely tied to the districts' curricula and standardized in their administration;

3. Pre-/post- or summative tasks specific to each science module that could be administered district-wide; and

4. Informal, unit-based assessments of a variety of different forms for classroom use.

Component 1. Finding a standardized test in science that was acceptable to all four districts was a source of continued frustration. A substitute was needed for

the SAT-9 which several districts had decided not to continue to use. Two of the partner districts adopted the TerraNova science test as part of more comprehensive district-wide adoptions, but four years after the plan was developed, there was still no Partnership-wide standardized assessment in science.

The lack of a common curriculum in the four districts poses a fundamental problem for summative assessment. Each of the four partner districts has selected somewhat different science modules containing different content in the tested grades, so no common assessment can be well-aligned with each district's curriculum. Moreover, most of the four districts chose to rotate the use of the modules among classrooms rather than purchase them for each classroom. That means that the sequence in which the modules have been used has varied across classrooms within a school and among schools. As a consequence, it is impossible to achieve high content alignment within a single school with any test administered in the spring because classes will vary in the modules that they have completed. This presents a challenge for performance assessments as well as for standardized tests.

Component 2. MISE took the lead in developing performance assessments for the second component of the plan. In the summer of 1999, MISE contracted with one of the developers of the performance tasks used in the Third International Mathematics and Science Study (TIMSS) to work with MISE staff and teachers from the Partnership districts in a joint venture. The intent was to identify available performance assessments that could be administered across the four Partnership districts. A working group including the consultant, teachers, and MISE staff met several times that year to review each partner district's curriculum, the available performance assessments, and which grades should be assessed. This was not an easy task. Each district had selected their own science modules, and there was variation in the modules used in any given grade. There also was variation in the sequence that was used across the schools in a district and within schools. Therefore, the working group decided that the performance assessments should focus on process skills rather than on particular content areas to avoid advantaging some districts over others.

The working group reviewed a wide range of performance tasks before settling on four TIMSS performance assessments: two for third-grade students called "Magnets and Plasticine," and two for seventh-grade students called "Solutions and Magnets." The tasks were piloted in the fall of 1999 in a sample of classrooms across the four districts and then administered in all third- and seventh-grade classrooms in the spring of 2000. They were re-administered with some modifications in the spring of 2001 and 2002, and additional assessments were selected for use in the fourth and eighth grades in 2002.

Piloting these assessments and then administering them across the four districts was an enormous endeavor and represented a substantial accomplishment by the Partnership. To avoid the biases that can come from differential administration, the Partnership developed standardized directions for administration. To further ensure uniform administration, the working group developed a method of documenting any assistance provided students by the teachers who administered the assessments. The Partnership revised the rubrics for scoring the assessments so that judgments of the quality of student work were reliable across multiple scorers.

To maximize the professional development potential of the experience, teachers from the Partnership districts were involved in most of the develop-

ment work for the performance assessments. At the end of October 1999, the Partnership held a multi-day workshop for teachers to score student work from the pilot, refine the rubrics, and analyze the information gleaned from the tasks. Teachers first reviewed the rubrics for assessing student work, then rolled up their sleeves and scored the work. A subset of the tasks was scored twice to assure inter-rate reliability. Teachers who participated in the workshop valued the experience; they felt that it was one of the most powerful professional activities they had ever experienced as teachers.

In subsequent years, students' work on the assessments have been scored externally, but teacher leaders have still gathered in the fall to examine and discuss the results. These teachers have led sessions in their districts focusing on what the results indicate about the strengths and weaknesses of student learning in science and the implications for curriculum and teaching strategies. These teachers have also worked with MISE staff to make modifications to the assessments and their administration. In 2001, an experiment was conducted in which some third graders were given time to examine the materials prior to the assessments.

Components 3 and 4. The demand for better informal unit assessments had been addressed in part prior to the development of the plan by distributing unit-based assessments developed by teachers and research scientists from the Educational Testing Service. The resulting grade-level binders contain more than 100 tasks and are widely distributed for teachers to use with the science modules. Shortly after the plan was adopted, district teams began to develop and test tasks to be used with science modules to satisfy the third component.

Other factors complicate student assessment. The focus of the Partnership's science instruction has been on inquiry, not recall. It may be that students who are learning to question and are engaged in inquiry are gaining significant skills and understanding that the standard assessments do not measure. Furthermore, not all of the teachers who teach science in grades K-8 have participated in the Partnership's professional development initiatives, and those who have, received varying amounts of training. Thus, not all students have access to Partnership-trained teachers, and students do not consistently have Partnership teachers from year to year. This makes it harder to measure any long-term effect of the use of inquiry-based instruction since measures of the average performance on standardized tests like the SAT-9 may mask the actual effects of the professional development.

It could also be that the Partnership's intervention has had weak effects on student performance. This seems unlikely given the observed changes in student activity and work done in class. Nevertheless, until adequate measures of student achievement are available, these questions will remain unresolved. MISE staff and district staff have administered performance assessments based on the TIMSS performance tasks. Taken by all students in grades 3 and 7 in the spring of 2000, 2001, and 2002, the results were useful for instructional planning, but did not produce reliable student scores. As a result, they did not help the Partnership solve the larger problem of developing a comprehensive assessment of student science learning in inquiry-centered classrooms.

Local, State, and National Policies

MISE is committed to making science education a local, state, and national priority, and regularly interacts with policymakers concurrent with its work in

the partner schools. At the *local* level, MISE works with district administrators and school board members by presenting the Partnership's work at public school board meetings or by having informal discussions to clarify issues or provide more in-depth information. Superintendents report changes in district policies as a result of MISE's influence including increased support for strong professional development, and improvements in hiring and recruitment practices that put more emphasis on a teacher's knowledge about content and inquiry-based instruction. At the *state* level, MISE staff serve on key committees such as New Jersey's Professional Teaching Standards Board which is responsible for setting high standards for teachers' professional development. Participation in these forums means that science education and MISE strategies can influence decisions that will impact teachers and students statewide. At the *national* level, MISE staff partner with leading educational organizations such as the National Science Resources Center and the Educational Testing Service to help develop inquiry-centered curriculum and assessment tools, and are frequently asked to share knowledge about their work with representatives from universities, corporations, museums, and school districts around the nation.

Conclusions

After 10 years of documenting the work of the Merck Institute for Science Education, CPRE researchers have reached the following conclusions about MISE's work:

- The concept of partnership has been critical to MISE's success. This idea has had a profound impact on MISE's approach to reform and its successful engagement of the four districts. Building a genuine partnership has transformed this reform effort from an externally funded project to shared work based on a common vision. The Partnership has sustained and deepened the reform effort, resulting in its integration with the regular operations of the four districts.

- MISE's systemic approach has worked. Science has become a priority in the partner districts. Inquiry-centered teaching has become the norm, most teachers have learned to use it well, and the districts are supporting it. Student work in science has changed dramatically and these changes have resulted in some improvement on standardized tests.

- MISE and its partners have not only learned how to provide high-quality professional development, they have learned how to provide it at considerable scale, and they have learned how to attract high proportions of teachers to participate.

- The provision of opportunities for teachers to acquire new knowledge and reflect on their practice, both through institutes and on the job, matters a great deal. The more professional development teachers receive, the more their classroom instruction resembles the vision of good practice advanced by MISE and the better the performance of their students.

- Sustained support for reform produces momentum and changes the norms of practice. When a critical mass of teachers in a school has received professional development and begun to change their practice, the practice of non-participants also begins to shift in the same direction. When norms change, new teachers are socialized and prepared to engage in the reformed practice through formal induction and informal learning from experienced peers. The atrophying effects of teacher and principal turnover are reduced and it

is easier to sustain the new practices (CPRE, 2001).

- Preparing Leader Teachers to act as catalysts of change in instructional practices across the classrooms of their schools produced mixed results as it was highly dependent on the support of the principal and the careful selection of the Leader Teachers. However, teacher leadership proved critical to this reform effort. By offering teachers authentic opportunities for leadership such as designing and delivering professional development, developing and implementing new tools of assessment, and leading study groups, MISE helped the districts build a competent, confident, and professional teaching force. The districts are able to sustain the work in large part due to the capacity of the teachers who have emerged as leaders through the work of the Partnership.

- A successful partnership such as this one also requires the ongoing support of school principals. They set the priorities in their schools; shape the norms of acceptable practice; determine whether teachers have time for planning, reflection, and discussion of instructional matters; explain the changes in classroom practice to parents; and find resources and provide support for a sustained reform. Principals must understand and embrace the vision of reformed practice and appreciate and support the teacher leaders who help spread it.

- The four partner districts have become active players and shaped the Partnership. They have adopted MISE's vision of instructional reform, and are actively supporting reformed practice. District staffs are now more attentive to how their policies and procedures affect classroom practice. The four districts have made changes in policy, organization, and assignments in support of MISE's vision of science instruction. They have internalized some key lessons drawn from this experience and, within their resource limitations, are applying what they have learned in language arts and mathematics.

- These changes have been given an assist by Merck's reputation, expertise, and commitment to public education which have enabled MISE to influence state policy and create an environment more supportive of the reforms.

- In terms of the bottom line — the improvement of student performance — classroom observations and interviews show that student work in science has shifted dramatically, from memorizing facts in textbooks to designing and conducting investigations that help students understand key concepts as well as the habits of mind and methods of inquiry used by scientists. Analyses of student performance on standardized tests reveal that students who have received science instruction over several years from teachers who have participated in the Partnership professional development outperform students who have been taught by non-participants. In spite of the assessment problems encountered by MISE and the Partnership, these data suggest that, in the long run, as more and more teachers participate in the workshops, there will be an increasing positive impact on student performance in science.

Important Lessons and Issues

The Partnership initiated by MISE has been a remarkable collaboration with an enviable track record of accomplishment. The experience of the Partnership, its

successes and shortcomings, and the challenges that it has faced offer lessons for other organizations that set out to help school districts improve teaching. Many of these apply to any reform effort. The most important lessons are:

- A shared vision and clear communication are critical to the eventual success or failure of a reform. MISE's advisory committee was a unique and important element of the Partnership, and helped provide the Partnership with valuable feedback to modify and enhance the work. The committee gave the Partnership's leaders a forum to address issues or concerns, share ideas, and make decisions affecting the work. Providing the Partnership's leaders with regular opportunities to meet and collaborate empowered the key stakeholders and gave each a voice in the Partnership's development and success.

- Respect for teachers and teaching is a prime directive. From the beginning, MISE staff showed respect for teachers as professionals and valued colleagues. They understood that teaching was demanding and complex work, that there were not always clear answers to the problems teachers faced, and that successful teachers were highly skilled professionals. This respect was evident in their voluntary approach to professional development, in the climate set in the institutes, in their concern about quality, and in their insistence that accomplished teachers help design and lead the professional development. This principle won them the respect of the teaching forces in the four districts. Even those who were unwilling to participate recognized that the "MISE folks understood teaching."

- If you build good professional development programs, teachers will come. CPRE's data show that the vast majority of teachers will voluntarily take advantage of opportunities to learn and to improve their teaching practice — if the opportunities are seen as worthwhile and are accessible. Offering professional development that is directly related to teachers' work, showing respect for their professionalism, carefully combining attention to subject-matter knowledge with skills in pedagogy, and classroom management of inquiry have proved to be a successful formula.

- Professional development must be a continuous process, not a set of episodes. Not only do teachers benefit from continued engagement with the content of the curriculum and opportunities to reflect on what students are learning, there is also constant turnover. Good teachers who have been trained depart, and each year there is an influx of new teachers who have to be brought up to par quickly. The reassignment of teachers to different grade levels after they have developed expertise with the curriculum at a given grade level also confounds systematic staff development planning. MISE and the partner districts have responded by building programs to introduce new teachers to inquiry and in which all new teachers are required to participate. These orientation programs are effective for introducing new staff to district instructional expectations, but considerable time is required for high levels of instructional proficiency.

- Given the current policies governing the preparation and assignment of elementary school teachers, there are limits on the changes that can be made in science teaching even with good professional development. Most elementary school teachers have little content knowledge in science to begin with, so it is difficult for them to reach

the level of content knowledge needed for successful inquiry-centered instruction. Many can only move part of the way toward reformed practice. They need the structure provided by the well-designed science modules and the structured investigations that are built into them. In addition, science competes with literacy and mathematics for instructional time in elementary school classrooms. Teachers may not be able to do inquiry every day because it takes considerable time to plan and carry out.

- Persistence is critical as it takes time for teachers to acquire the knowledge, skills, and confidence to change their practices, and even longer to alter the norms of practice. MISE has worked with the four partner districts for a decade. One of the important roles that they played was to keep people focused on the reform. Many competing interests pulled at people's time and attention. Keeping the interest of the reform at the top of the agenda is not an easy task and takes skill, patience, and tenacity.

- Personnel changes are common in school districts, and this turnover is the enemy of persistence and, therefore, of success. Superintendents, school boards, curriculum supervisors, principals, and teacher leaders come and go. Since 1993, MISE has worked with 14 superintendents in the four districts. The annual turnover of teachers was about 6%. However, the broad participation in the work and the widespread respect that it garnered made it possible to sustain the reforms in spite of the turnover in personnel. MISE staff kept top leadership informed and educated along the way and garnered their support and approval. They built support for the effort among all of the stakeholders so that the loss of one leader did not bring the effort to a halt. This has been a time-consuming and delicate process, but also an important role that MISE was well positioned to play. Merck's reputation for quality and integrity have been important in sustaining the work of the Partnership through numerous leadership transitions.

- Teachers' knowledge and skills are critical factors in the classroom learning experience, but not the only ones. Good curriculum materials are also essential. Teachers need access to and support in implementing standards-based curricula and teaching materials. They need the support and knowledgeable involvement of school- and district-level administrators, parents, and the community. MISE addresses these needs through resource centers featuring exemplary science education materials, Merck employee volunteer programs, and parent involvement programs, in addition to its support of long-term professional development.

- Better assessment tools in science are needed. Existing measures do not adequately show the effects of better science instruction. Right now, teachers see improved student work in their classrooms and a higher level of student interest in science, but the available measures do not adequately demonstrate this change to parents, school leaders, or the public. In addition to assessments that provide good diagnostic information for teachers' instructional planning, assessments that are persuasive to the public and policymakers are needed as well.

- The state policy context on incentives for change can play a pivotal role in stimulating instructional reform, and MISE's role in shaping state policy has had a high payoff. Including

science in state assessments is particularly important. If science is not assessed, attention shifts to the assessed subjects and it becomes difficult to engage teachers in serious instructional reforms. This problem can be countered if district leaders make science a priority and include it in internal accountability processes.

Final Thoughts

MISE is a compelling example of a technical assistance organization that has developed a coherent approach to reform and paid careful attention to feedback from the field and from evaluation to modify its strategy as needed. The success of the Partnership is testimony to MISE's thoughtful strategy, patient responsiveness, and willingness to make changes. Each year, CPRE evaluators reviewed their findings with MISE staff who then used the information to alter the course of their work. MISE is a learning organization, and it has modified its tactics as needed. Learning that the Leader Teacher strategy was not effectively spreading good practice, MISE altered its approach to professional development to engage hundreds of teachers through Peer Teacher Workshops. Finding that existing curricular guidance and assessment tools were inadequate, MISE staff developed local curriculum frameworks and new assessments. Recognizing that state policies were limiting the reforms in the districts, MISE staff actively sought to create a more supportive policy environment, participating in the development of state standards and curriculum frameworks, engaging in public outreach, and networking with other business-school partnerships, thereby broadening the base for reform.

MISE formed partnerships with the four districts that were based on mutual respect, frankness, and honesty, and they blossomed into one common Partnership with a shared vision of reform. This increased the likelihood that the collective effort would be sustained over time; since everyone was a player in the decision-making process, everyone had a stake in the results.

MISE understood that a systemic approach was needed in order for this initiative to have the desired impact of bringing real change to science instruction. Without a systemic approach, it is likely that the Partnership would have been less effective. By working at every level with school districts, by being mindful of the political nuances of each setting, and by addressing issues of time and professional development, MISE increased the effectiveness of its efforts.

The MISE Partnership, in addition to being a story of real accomplishments, is an incomplete story. It is an incomplete story because as yet, there are not the broad-based student achievement results needed to support the assertions of teachers, administrators, MISE staff, and even CPRE evaluators that students are learning more science. This is a critical and important point that is being addressed by MISE but which leaves an empty space in this success story.

With all of the intensive, high-quality professional development that was part of the Merck venture, it is still sobering to realize that most teachers need between 80 and 100 hours of professional development to produce significant change in instruction. The extension of this fact to other districts in the two states underscores the need for enormous funding support and patience in order to see the changes in practice needed to ensure that all children receive a sound science education.

This is a partnership worthy of modeling. The example is there not only for other corporations to follow, but for all technical assistance organizations whether they be sponsored by states,

universities, non-profit organizations, or professional organizations. There are similar stories to be told about the El Paso Collaborative for Academic Excellence, the Bay Area School Reform Collaborative, the Southern Maine Collaborative, and other organizations that have focused on particular communities or regions and provided the intense and sustained assistance needed to make significant changes in teaching. After almost a decade of financial support, sustained professional development, and management guidance, the four school districts working with MISE have made dramatic changes to their K-8 science programs. Children have access to better science materials and teachers are more comfortable with their teaching. The success of MISE and the Partnership demonstrates that serious efforts to help teachers improve their practice brought positive results, and that students benefited from these investments.

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