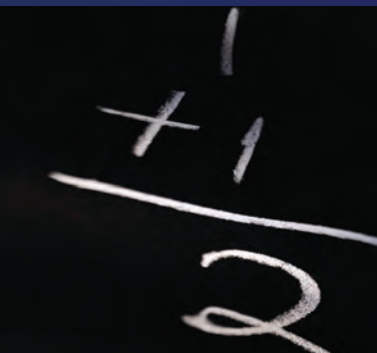
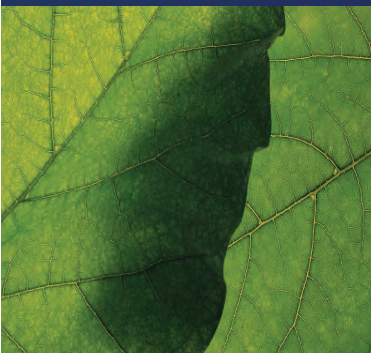


The Quest for Coherence



MICHIGAN STATE
UNIVERSITY

PROM/SE is a comprehensive research and development effort to improve mathematics and science teaching and learning in grades K-12, based on assessment of students and teachers, improvement of standards and frameworks, and capacity building with teachers and administrators.

PROM/SE is a collaboration of the Michigan State University College of Education and the College of Natural Science.

PROM/SE

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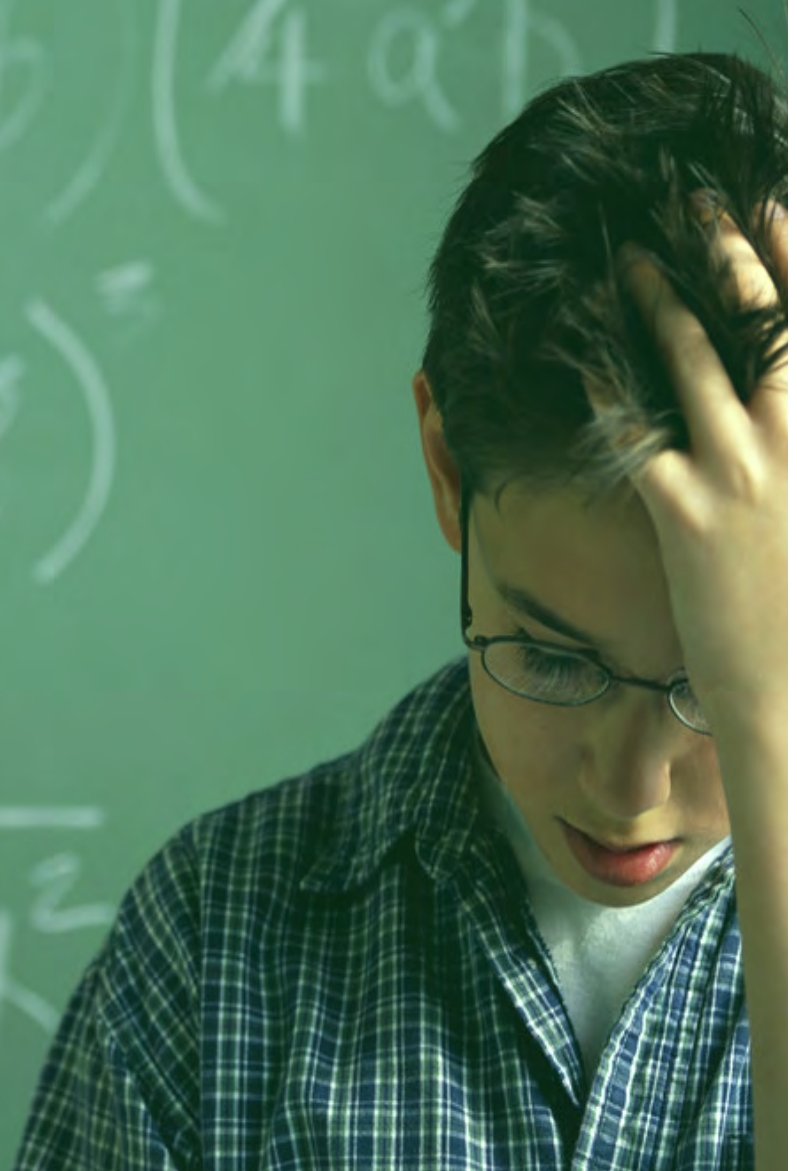
**PROM/SE Quest for
Coherence Report**

Editor: Susan Pettit-Riley

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The Quest for Coherence

PROMOTING RIGOROUS OUTCOMES IN MATHEMATICS AND SCIENCE EDUCATION (PROM/SE)

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INTRODUCTION

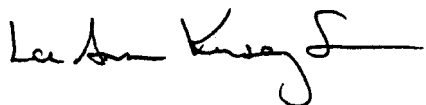
Mathematics and Science education in our country has been analogous to 1000 points of light without circuitry. PROM/SE has the potential to join the pieces. When PROM/SE started in 2003 it was hard to imagine the current national debate on science, technology, engineering and mathematics (STEM) education or the development of the Common Core State Standards for Mathematics (CCSSM) by the National Governors Association and the Council of Chief State School Officers. Now, STEM has become a national imperative listed by President Obama as a top agenda item. The CCSSM has been adopted by a vast majority of states. Our national call is to improve student achievement in mathematics and science so that all students will graduate with the skills needed to be competitive in a world economy based on technology. A solution to student improvement in mathematics and science will require a level of boldness that really captures the imagination of teachers, policy makers, and the public.

Research findings from PROM/SE have the potential to have an enormous impact on the national stage of education reform. Policy makers and educational leaders are looking for projects with real data - both high school and elementary - that in a meaningful way can tie the elements together which lead to improved student achievement. It is the role of a land grant university to care about these issues and MSU is passionately committed to reform in this area.

The unprecedented amount of data generated from a project the size of PROM/SE provides a basis for moving more rapidly forward with improvements for changing curriculum and teacher training. Combined with other MSU resources, they all make up a 1000 points of light and a unique place in time for MSU to be a leader in mathematics and science improvements.

Collaboration between the Colleges of Education and Natural Science, along with funding by the National Science Foundation, gave rise to PROM/SE and is part of MSU's on-going commitment to STEM education. MSU's College of Education now has more than 20 tenure stream faculty members in mathematics and science education. Collaborative programs through the Division of Science and Mathematics Education boost the efforts of faculty in departments across campus in preparing our students for STEM careers and attract faculty committed to implementing and advancing effective teaching practices.

MSU has a strong tradition of outreach and partnership with K-12 school districts. Through PROM/SE, we have touched more than 60 school districts in Michigan and Ohio in our efforts to improve student achievement. Children will need strong mathematics and science skills to succeed in school and life. The PROM/SE project is an affirmation of the passion MSU has for making a difference in the lives of children every day.



Lou Anna K. Simon
President, Michigan State University



CHAPTER 1 / The Story of PROM/SE

The announcement of Promoting Rigorous Outcomes in Mathematics and Science Education (PROM/SE) in the summer of 2003 was a remarkable moment for MSU and its involvement in schools and K-12 educational reform. The National Science Foundation awarded MSU and five consortia of school districts in Michigan and Ohio a \$35 million grant to fund the research and development initiative. PROM/SE sought powerful new approaches to improving K–12 student achievement in mathematics and science that would bring U.S. student achievement up to par with international standards.

PROM/SE was large in its scale, cutting a swath through middle America and involving nearly 7,000 teachers and 300,000 students from districts large and small, wealthy and not. Some 37 percent of those students came from impoverished households in rural or urban areas. Because the project worked with data derived from a representative microcosm of the United States, the results have the potential to be broadly applicable to researchers and policymakers nationwide.

The project sought to answer how to successfully create and sustain change in student achievement on a large scale. For PROM/SE, the theory of how to improve achievement for all children was rather straightforward: we needed to understand what students know, what was expected of students based on the standards, what teachers taught, and then improve and align all three.

PROM/SE had a unique approach of collecting a wealth of data from many sources within nearly 60 participating school districts and then using it to analyze the relationship between curriculum, teacher training and knowledge, parental involvement, and student achievement. At the outset and at regular intervals throughout the project, students in grades 3–12 across the partner sites were assessed in mathematics and science. Teachers were surveyed about their background, knowledge, and topics they taught. Districts were surveyed about their standards, instructional materials, and professional development.



On the basis of obtained data, we reviewed standards and analyzed the alignment of standards with instructional materials and teaching practice, all against the backdrop of international benchmarks from the Third International Mathematics and Science Study (TIMSS), and provided professional development for teacher leaders, teachers, and administrators. Related reform in the MSU teacher education program was undertaken during this same period in conjunction with the Teachers for a New Era initiative.

The Goal of Coherence

The challenges of improving the teaching and learning of K–12 mathematics and science in America are daunting. Repercussions are still being felt from the landmark 1995 TIMSS when the poor performance of U.S. students rattled American educational leaders. Although American fourth-graders scored near the top in science—outperformed only by South Korea and Japan—and slightly above the international average in mathematics, TIMSS chronicled a steep decline in achievement through middle and high school. In the eighth grade, U.S. students’ scores dipped below the international average in science and mathematics. It was even worse by the end of high school: American seniors could outperform only two nations—Cyprus and South Africa—in mathematics, and in physics they finished at the bottom, outscored by every other country in that portion of the study.

Since TIMSS, studies have consistently found that U.S. students still lag behind their international peers in mathematics and science knowledge; that levels of achievement are inadequate; and that there are widening achievement gaps between black and white students in affluent and poor schools (National Center for Education Statistics, 1996, 1997, 1998, 2000, 2001). In order for students to compete with their international peers for jobs in the world economy, the American educational system has to ensure that students receive the best education possible with the goal of raising student achievement on a large scale.

PROM/SE was based on the premise that all students should have an equal shot at taking and succeeding in advanced mathematics and science courses, benefiting from well trained teachers knowledgeable in mathematics and science, and learning from a coherent curriculum. PROM/SE defined a coherent curriculum as being focused, rigorous, logical with a hierarchical organization containing clearly articulated concepts developed within and across grades, and designed to deepen and expand student understanding with each new experience.

TIMSS demonstrated that the U.S. mathematics and science school curriculum was weak compared to international standards. For example, while most U.S. middle school students studied arithmetic and the descriptive aspects of geology and biology, typically their counterparts in other countries studied algebra and geometry, physics and chemistry (Schmidt & McKnight, 1995; Schmidt, McKnight & Raizen, 1997; Schmidt et al., 1997). Efforts to produce high quality national standards (National Council of Teachers of Mathematics [NCTM], 2000; National Research Council [NRC], 1996) have intended to address such problems. The role of teachers in instruction is also crucial. In 1996, the National Commission on Teaching and America's Future (NCTAF) argued that what teachers knew and did in the classroom mattered for pupil learning, and that teacher preparation may be a viable policy tool to improve the quality of education in the U.S. (NCTAF, 1996). Yet research had failed to demonstrate a clear relationship between teacher knowledge and student learning (see Wilson, Floden, & Ferrini-Mundy, 2002), and the studies that did hint at a relationship (e.g. Monk, 1994) provide only general guidance about how teacher education might be reformed in terms of teachers' content preparation. Data also indicated that few professional development programs were content driven (Kennedy, 1998).

Based on the extant literature we at PROM/SE believed that the essential ingredient for improving both mathematics and science achievement for all children was coherent, challenging content standards that were supported by properly aligned textbooks, instructional materials, and course taking policies. These standards, textbooks, and materials needed to be used by teachers who had a deep understanding of subject matter knowledge and subject matter knowledge for teaching.

The conceptual model for PROM/SE, adapted from Schmidt et al. (2001), when applied to data in more than 30 countries indicated a strong empirical relationship between curriculum and student learning. Student learning referred to what students acquired in some specified period of time, e.g., gains across one grade level. We took teacher knowledge to include knowledge of subject, knowledge of pedagogy specific to the discipline, and knowledge of students.

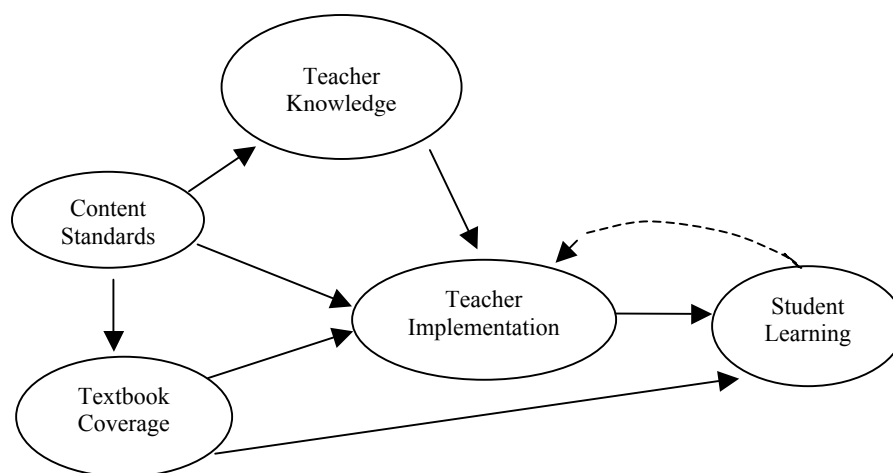


Figure 1. A Path Model of Student Learning

Each path in Figure 1 represents a complex social relationship between the related nodes. For example, the path between “content standards” and “textbook coverage” indicated that officially articulated goals affected the content of textbooks. Similarly, content standards may influence the preparation or the continued professional development of teachers, and thus in turn influence teaching practice. How teachers choose to use their classroom time was related to textbook coverage. And, what got taught was related to what students learn. What students learn in turn informed teaching practice. The model suggested two interrelated foci for improving student learning: curriculum (including textbooks and standards), and what teachers know about mathematics and science, as well as about their students as learners. The first focus was the teacher preparation and professional development nexus, which was centered on the proposed connections among content standards, teacher knowledge, and teaching practice. The curriculum nexus centered on the interrelationships of standards, textbooks and teaching practice, which was the other major focus of PROM/SE.

The Difference is in the Data

While there had been plenty of large scale educational projects devoted to student achievement, what made PROM/SE somewhat unique was its belief that for real and sustained change to occur, district administrators needed to have detailed data about what was going on in their districts in regards to mathematics and science. Data collected by PROM/SE was not just about passing or failing and went much deeper than the standardized test scores districts were accustomed to seeing. Using insights gained from the TIMSS data, the project designed data collection activities and amassed piles of data from participating districts to give them a detailed view of their students, teachers, and curriculum.

Participation in PROM/SE required school districts to be open to a new approach, one that did not promise immediate results for their students. District administrators, many familiar with past reform efforts that showed mediocre results, were intrigued by the level of data promised, if only partially convinced that the findings would be of use to them. Some districts were hesitant to devote their limited and often stretched staff resources needed to coordinate the data collection and participation throughout the multi-year project. Surprisingly, smaller districts participated more readily than their larger peers, perhaps because they had fewer opportunities to participate in research or because their smaller size lent itself to greater flexibility. However, in every case, district superintendents who signed on to participate in PROM/SE exhibited a courageous dedication to seeking new answers in improving the lives and learning of their students.

Much of the first year of the project was devoted to building a shared understanding of the power of data and its value to districts when put to use. While using data is so fundamental to our lives, we often are not conscious of it. Something as commonplace as buying shoes, for example, involves collecting and analyzing data across a number of issues. What kind of shoes do I need? Are they available in my size? Are they the right price? A great price isn't a good buy if the shoes don't fit.

PROM/SE took the same approach to efforts to improve mathematics and science education. To be effective, new approaches needed to fit the individual circumstances within each district. Because district administrators and teachers had varying experience in interpreting large data sets, PROM/SE held sessions with administrators and teachers on how to interpret the district-level data they were more accustomed to seeing from their states as well as the complex data sets provided by PROM/SE.

The goal was to present teachers and administrators with the fullest possible understanding of their particular educational context. This is why PROM/SE began with exceptionally detailed data on student performance- much richer data than is typically provided by state assessments. PROM/SE provided data on curriculum, classroom instruction, student and teacher backgrounds, and school administration. The PROM/SE team developed assessments and tested students at regular intervals throughout the project to see how much their learning had improved. Teachers were also surveyed about their classroom practices and subject matter knowledge. Staff worked with school districts to collect data about K–12 mathematics and science curricula, student learning, teacher professional development, teacher preparedness, and parents' attitudes about mathematics and science education.

The information provided PROM/SE and the districts a kind of bird's eye view of how students fared compared to each district's curriculum and state standards, the amount of time spent on particular topics within the classroom, and how well that time allocation translated into student understanding. The project worked closely with superintendents and curriculum directors in each district to understand what was working in their districts and assisted them in developing strategies to improve what was not.

Teachers and administrators in participating schools now have unprecedented access to extremely rich student and context data at the building and district level, across the partnership, and at the national and international level. They also have comparative data on instructional approaches and time spent on specific sub-topics that can help guide them in choosing how best to focus their efforts to improve student performance. The PROM/SE belief is that better, more precise data will enable teachers and administrators to make better-informed decisions about what their students need in order to achieve, and what each teacher needs in terms of organization and professional development to achieve these goals.

Distributed Knowledge and Capacity Building

Fundamental to PROM/SE's design was the belief that it was critical to the improvement of mathematics and science teaching and learning that key actors at several layers of the system had access to particular knowledge, skills, and resources, and that collectively they had commitment and motivation to deploy this expertise toward improvement. Central to this thesis was the view that at every level, an understanding and use of data is an important feature of the improvement process.

First, we were committed to the view that empirical data, assembled in sophisticated ways that reflect interrelationships among key variables, was a central resource for the improvement of student learning and performance. We hypothesized that by assembling data about student performance, alignment of curricular standards with state and international standards, teachers' time spent on mathematics and science topics, instructional practices, district professional development experiences, and teachers' characteristics and knowledge of mathematics and science for teaching, we could provide teachers, school and district administrators, consortium leaders, and higher education institutions with a unique basis from which to identify key challenges or barriers to improving mathematics and science teaching and learning.

One of the objectives of this first component was for teachers to be able to coordinate what they learned from the systematically gathered empirical data available in large scale assessments and surveys with the daily “data” that they amassed in their own classrooms, as they taught, i.e. student assessment data derived in the context of teaching. We viewed this layered distribution of knowledge to be crucial – some aspects were more crucial for various players in different parts of the system than for others.

The second area that we believed to be crucial for improvement of the system was distributed subject matter knowledge in mathematics and science – knowledge that is relevant to the challenge of teaching to high standards and to holding high and attainable expectations for students. By “distributed”, we meant that not every teacher and administrator would need to be expert in all relevant areas of mathematics and science. The challenges of working with state standards that may or may not be focused, coherent, and aimed at significant mathematics were substantial. Because the idea of challenging, coherent standards was a primary theme in PROM/SE, the partners in the project needed to develop capacity to be critical connoisseurs of state and local standards. We believed this required mathematical and scientific knowledge that enabled them to judge which standards were more important than others; how ideas were best sequenced and developed; which standards were “power standards” in that they function as lynchpins, or keys, to others; how to determine whether instructional materials aligned to standards and how to emphasize key areas, how to supplement wisely, and how to judge the implications of ignoring particular areas.

According to the PROM/SE model, the third type of capacity that must be built was the ability among several levels and roles in the system to broker resources for colleagues who worked to improve their mathematics and science teaching and learning in their classrooms, schools, districts, or consortia. This component had several facets which involved helping a larger set of people in the system be prepared to work with adult learners as leaders and facilitators who could help their colleagues access new information, skills, and tools. It also involved knowing about what tools, resources, and materials were available. It involved being able to diagnose what kinds of resources would best help address the local goals and intentions in a particular setting, and then access those resources.



Figure 2. PROM/SE Cycle

Use of Data in Designing Professional Development

To focus and refine districts curricular expectations and practices, the following cycle (Figure 2) was consistently used with the PROM/SE partners and teachers to frame PROM/SE activities in relationship to the data.

All PROM/SE Professional Development topics addressed knowledge gaps and areas that needed improvement as indicated by the data. PROM/SE joined experts in mathematics, science and education from MSU and elsewhere with district administrators and teachers for customized professional development. For administrators, PROM/SE offered peer networking, leadership development and data interpretation. Teachers were offered learning opportunities to facilitate deeper content knowledge aligned with state expectations, benchmarks, and indicators. More than 5,000 K-12 mathematics and science teachers attended PROM/SE led professional development academies held during the summer and throughout the school year. All sessions were held in central locations in Michigan and Ohio.

PROM/SE professional development included:

- Superintendent summits
- District curriculum directors quarterly meetings
- Data interpretation workshops for administrators and teachers
- Principal leadership sessions
- School Counselor workshops
- Teacher workshops on specific content areas held during the academic year
- Summer academies
- Building Coherent Mathematics Curricula workshops
- Building Coherent Science Curricula workshops
- Virtual Professional Development

Use of Data with Teachers

Using the data displays that compared state standards with the TIMSS high achieving countries, we designed professional development activities that focused on related ideas we felt may be groundbreaking in terms of their introduction in mathematics and science teacher professional development. In particular, we developed the notion of *curricular content trajectories* (i.e. the logical and sequential development of mathematics content within and across grades) as a foundation for teacher professional development. We helped teachers to identify trajectories within standards and in instructional materials. Towards these goals, PROM/SE opportunities for teachers were designed to:

- deepen teachers' mathematical and scientific knowledge for teaching
- build on data, both from PROM/SE and other relevant sources
- help teachers gain familiarity with and be able to relate to content standards
- draw explicitly on topic specific research on teaching and learning
- develop understanding of content trajectories within and across grade spans
- deepen teachers' knowledge of cognitive demands of tasks.

Results from the PROM/SE student achievement assessments and teacher background knowledge surveys coupled with information about curriculum, served as the foundation for selecting the focal content areas for intensive professional development. The project leadership identified areas where students showed particular weakness in an absolute and relative sense compared to the TIMSS high-achieving countries.

Virtual Professional Development (VPD)

A particularly important part of the VPD was the development of the Coherent Curriculum Transformer (CCT). The CCT was designed to support and encourage curriculum coherence. The system collected information about a school's curriculum and every lesson was entered into the web-based system and

“tagged” with an item or items in the Common Core State Standards for Mathematics. In this way, several common curriculum problems were revealed. The CCT helped visualize which content areas were over-taught, under-taught, or taught out of sequence.

In addition, the VPD provided teachers with access to experts with content and pedagogical knowledge. Through hundreds of video/slide presentations, prominent teacher educators presented material that was integrated into VPD Mini Courses. A teacher selected materials based on immediate need and amount of time available. Instructional material ranged from a few minutes (for quick classroom lesson suggestions), to courses that took several weeks to complete. Over 150 VPD video segments have been developed with 36 video segments for mathematics mini-courses.

Two-way dialoging allowed a teacher to discuss questions on-line with a mentor. The teacher and mentor carried on a public discussion. Unlike the expectation of major social networking websites, the expectation here was for thoughtful discussion. This set of features encouraged questions from teachers about the curriculum through a closed messaging system. When an answer was complete, the mentor and teacher captured the question and answer and the question/answer pair became part of the knowledge base.

Use of Data with Future Teachers

PROM/SE included a component that focused on improving the pre-service education of future mathematics and science teachers. This component was coordinated with MSU’s Teachers for a New Era initiative (<http://www.tne.msu.edu/>) and was supported by the Carnegie Corporation, the Ford Foundation, and the Annenberg Foundation. Data from PROM/SE and other sources delineated the kinds of subject matter knowledge future teachers needed in order to improve student learning. This information was used to revise and develop university courses for future teachers.

PROM/SE Professional Development from a New Angle

Associates (PROM/SE teacher leaders) and their teaching colleagues attended intensive courses designed by PROM/SE to build a distributed expertise that would impact curricular change. Sessions differed from traditional professional development offerings that provided teachers with exercises they could use the next day in the classroom.

“PROM/SE PD aimed to develop a deeper understanding of topics in order for teachers to engage in discussions that build a coherent curriculum and their knowledge for teaching mathematics and science,” said Mary Bouck, PROM/SE director of capacity building. Teachers and administrators were encouraged to take what they learned and share it with other colleagues in their buildings and school districts.

Through these courses teachers learned to support and appreciate the power and complexity of student mathematical and scientific thinking. Courses also addressed common student misperceptions and developed shared strategies to increase student understanding.

Mathematics Professional Development

Teachers attending one mathematics academy focused on geometric principles and relationships, and examined angles – from every angle. “If teachers have a deep knowledge of mathematics, they will become more confident and comfortable, and this will help students develop their knowledge of mathematics,” said Gail Burrill, PROM/SE co-director of mathematics. “It’s not just about teaching mathematical rules and processes, but digging underneath for a better understanding of why those rules and processes make sense.”

PROM/SE worked closely with mathematics educators, mathematicians and K-12 representatives to design courses that addressed gaps in knowledge identified through the student assessments and the teacher surveys. The mathematics professional development also utilized the Breakthrough Mathematics Modules produced by LessonLab, Math Solutions by Marilyn Burns Education Associates, Developing Mathematical Ideas from the Center for the Development of Teaching, Education Development Center and the Common Core State Standards for Mathematics

Renowned mathematics educator Hung-Hsi Wu, a professor of mathematics at the University of California Berkeley taught a course on understanding fractions for K-6 elementary teachers. He felt that teaching teachers the fundamentals of mathematics is important. “Mathematics is, on the whole, like a pyramid. Students need a solid understanding of basic concepts on which to build,” noted Wu. Emphasis on learning foundational concepts such as whole numbers, fractions and certain aspects of geometry are critical to later success in algebra and follow recommendations by the National Math Panel.

PROM/SE professional development aimed to help teachers understand key mathematical and science concepts taught two grades below and beyond their class so that teachers can tie together these concepts in their classroom and help students understand broad themes or big ideas that unfold. Mathematics topics included: The Mathematics of Change, Making Decisions Based on Data and Chance, Geometry and Measurement, Whole Numbers, Rational Numbers, Equations and Lines, and Fractions.

Science Professional Development

Unlike mathematics in which key concepts and skills build on one another, science as a discipline is often fractured into seemingly unrelated subjects such as biology, chemistry and physics, where the connections between and among the big ideas are often lost as the student moves from one course to another. PROM/SE science professional development focused on the big ideas that crossed traditional discipline boundaries. Sessions were designed around the unifying theme of Systems and the unifying principle

of Energy. In one institute the relationship between the Sun, Earth, and Moon was explored. Assessments showed that teachers began the workshop with a diverse set of understandings about these relationships. Activities were designed to challenge those understandings. “This session showed me that I was wrong about what causes the phases of the Moon. I had a general background with some vocabulary, but I had not taught or studied this before,” a science Associate commented. “I learned that teachers in different districts and grade levels had just as many questions and misconceptions as I did.”

PROM/SE science professional development helped teachers respond to questions about key scientific concepts from students at all levels. PROM/SE also offered three inter-related sessions called “The Evolution of Everything”, which helped science Associates and teachers explain change in the physical and biological systems from the big scale to the small, including the origin and evolution of the universe, Earth, and life.

“The concepts of physical and biological change run through the entire K-12 science curriculum,” said Danita Brandt, PROM/SE director of science and a professor in the Department of Geological Sciences. “For example, talking about the breakdown of rocks and the development of soil are two small-scale changes that lie along the continuum of changes that began at the Big Bang.”

The series explored the origin and evolution of the universe including the Big Bang, galaxies, stars and our solar system and the evolution of the elements from which all matter is made. The “Origin and Evolution of Earth” session addressed the question of how did the surface of the Earth get to look like it does today. Finally, a session on the origin and evolution of life continued the theme of physical and organic change through time, and the issues that teachers face when teaching organic evolution. Brandt noted that in parallel with the content, teachers also explored the nature of scientific inquiry and student scientific reasoning.



CHAPTER 2 / Building Partnerships

Partnership was a key feature of the PROM/SE project from its inception. Seeking to understand what it took to improve student achievement on a large scale and gather data from a wide variety of districts, PROM/SE sought out partner institutions whose demographics mirrored a microcosm of the United States and were diverse from each other economically, racially and geographically. Another key criteria in choosing project partners was to find institutions that had strong relationships with their district members, an active network developed for sharing information between its districts, a commitment to the improvement of mathematics and science, and past experience working with Michigan State University on educational research projects.

PROM/SE involved partnerships between MSU's Colleges of Natural Science and Education and five institutions including three intermediate school districts in Michigan: Calhoun County ISD, Ingham County ISD and St. Clair County RESA, and two consortiums serving school districts in Ohio: High AIMS serving greater Cincinnati and SMART serving greater Cleveland. For a list of school districts participating in PROM/SE see the appendix.

Together these five institutional partners allowed the project to reach nearly:

- 60 school districts in Michigan and Ohio
- 1000 PROM/SE Associates (teacher leaders)
- 5000 in-service teachers and 800 pre-service teachers
- 300,000 K-12 students

District participation in the PROM/SE program was voluntary, raising the question of how typical or representative the PROM/SE student population was of other larger population groups. To provide some insight on this question, the student population of the participating PROM/SE districts was compared to the U.S. student population on a variety of background factors that are commonly believed to be related to student achievement. School district level data from the U.S. census of 2000 was used for this comparison.

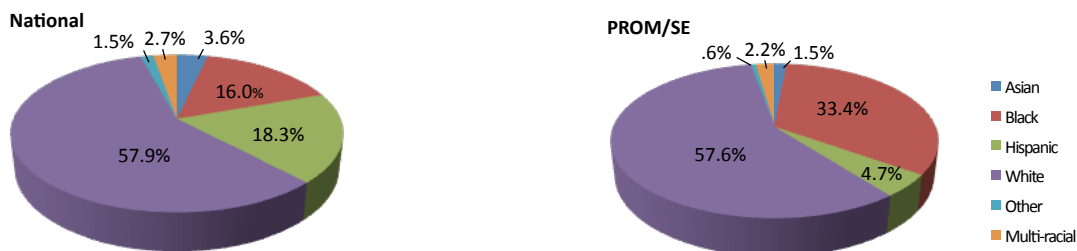
The specific approach used for comparing students in PROM/SE school districts with equivalent students at the national level involved three types of comparisons. The first set of comparisons involved personal student attributes including the student's racial and ethnic group, the student's ability to speak the English language and the longevity of the student at their current residential location. A second set of comparisons involved the student's household. Household factors examined included: the presence and number of parents in the household, household income level in 1999, household income relative to the national poverty level in 1999, the level of urbanization of the location of the residence, and nature of residential occupation, rental or ownership. The final factor set involved characteristics of the student's parents, specifically the educational achievement level of the parents.



Students from PROM/SE districts generally paralleled national averages with four exceptions. The PROM/SE districts reflected:

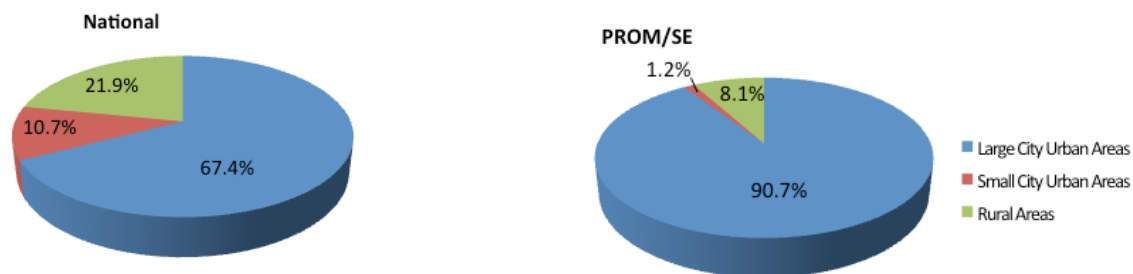
- a larger proportion of Black or African-American students,
- a smaller proportion of Hispanic students,
- a larger proportion of students residing in large city urban areas,
- a smaller proportion of students residing in small city urban areas.

Figure 3. Racial/Ethnic Distribution



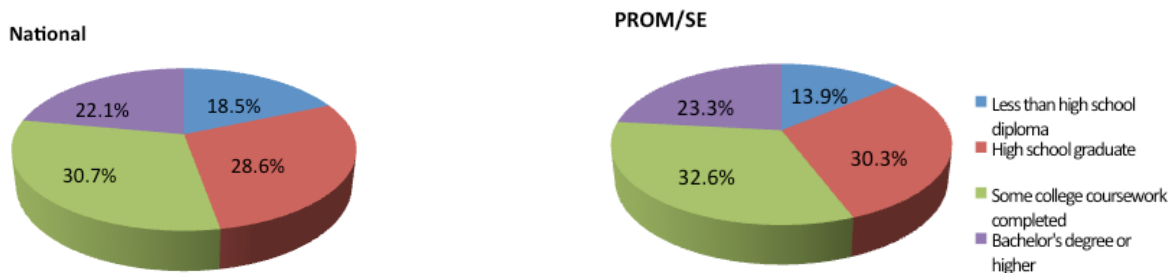
All major racial ethnic groups were represented but with an over-representation of Blacks and an under-representation of Hispanics. The PROM/SE racial/ethnic distribution would be typical of much of the nation with the exception of the Southwest.

Figure 4. Residential Location



The total student population in PROM/SE districts was weighted in favor of Large City Urban Areas. Rural areas were only slightly underrepresented in the student population from PROM/SE districts. Small city urban areas, although present, were significantly underrepresented.

Figure 5. Parents' Education Level



Students from PROM/SE districts were somewhat less likely to have parents who were not high school graduates and somewhat more likely to have parents with educational levels in each of the remaining higher categories of education.

The Power of Partnership

by Terry Krivak, Smart Consortium

PROMSE and its five institutional partners had a common goal – collaboration with the intent to improve K-12 teaching and student learning in mathematics and science. When SMART became one of the partners with PROM/SE, we saw this as an opportunity to dramatically impact education in our region and to provide a bridge between school districts and academic research.

SMART- Science and Mathematics Achievement Required for Tomorrow- is a consortium of school districts in the greater Cleveland, Ohio area. Spurred by the TIMSS results and the poor performance of Ohio students, SMART was established with the mission to improve K-12 student achievement and teaching in mathematics and science through partnering with local school districts. The High AIMS consortium was formed around the same time to serve greater Cincinnati.

SMART's strong collaborative nature includes a management structure in which the superintendents of the participating districts agree upon a common agenda, ensuring that all initiatives are driven jointly across the districts. SMART had already established a leadership program for mathematics and science education at the superintendent and principal levels. However, until PROM/SE we did not have the ability to collect data on what was and wasn't working across districts.

Collaboration is not that common in our business. However, collaboration sets the stage for leveraging resources and joint decision-making on areas of high importance. It is difficult for an individual school or district to impact the teaching of mathematics and science on a large and meaningful scale. As a result districts often struggle to achieve substantial or sustainable improvements in student achievement. When you consider the large number of classrooms in each district and the individual nature of the K-12 teaching environment it is a formidable task to make the changes that are needed for improvement.

We believe these challenges are best met through partnerships. MSU provided the funding and the expertise in methodology and data analysis districts lacked. Districts provided access to students, teachers, and staff for testing. Teachers committed to attending intensive professional development.

In a multi-year study like PROM/SE the research benefits are not always immediate. There are limitations and risks. School administrators are limited in how far they can push their teaching staff to make the needed changes. They must take risks when making changes and provide strong leadership. When school districts work together and tackle the challenges collectively it helps them raise their risk level and set higher-level goals to improve student achievement.

Teachers willing to implement the changes often find it difficult to be successful without support from other staff members in the building and district leaders. Through PROM/SE there is now a large network of over 1000 teachers who have participated in intensive professional development and serve as resources for other teachers in their building. The research component of PROM/SE helped teachers see the impact of specific changes in their classroom and building, and motivated teachers to improve their skills.

Now that the project has ended, the most challenging aspects are to come. Teachers and administrators saw the value of collaboration, and the challenge will be to maintain this momentum within each district. As a whole we firmly believe that this is necessary to support long term and sustainable improvement in student learning and the teaching of mathematics and science.

Terry Krivak, Ph.D., is the former executive director of the SMART Consortium, and has served as a Superintendent and teacher.

CHAPTER 3 / Quest for Coherence

“A curriculum is more than a collection of activities: it must be **coherent**, focused on important mathematics, and well articulated across the grades” (NCTM, 2000).

A PROM/SE hypothesis was that curriculum coherence matters in student achievement. To help districts achieve a more coherent curriculum, PROM/SE worked at both the micro and macro level. PROM/SE designed and conducted intensive professional development to focus on deepening content knowledge for teaching. Part of this work included building curriculum coherence on the micro level through developing teachers understanding of the logical, hierarchical organization of a topic at their level (elementary, middle, or high) and within their grade. Macro level coherence was sought through improving cross-grade coherence with district curricular teams (curriculum specialists, building administrators, and teachers). This chapter discusses the macro approach in detail. The third strategy of building coherence through the use of data to support curricular change will be explored in depth in a later chapter.

Curriculum Coherence Institutes

From 2007-2009 PROM/SE met with district mathematics leadership teams to build leaders’ capacity to create and maintain a coherent curriculum. Teams of administrators and teachers analyzed their current curriculum, and then planned how their team could work together to develop a more coherent curriculum that in the long run would improve student achievement. District leadership team members included lead teachers at each level (lower elementary, upper elementary, middle, and high), department chairs and math coaches, principals, and district administrators responsible for the mathematics program.

The institute sessions addressed:

- Defining and developing understanding of what constitutes a coherent curriculum within and across grades K-12 as it relates to the intended, implemented, and achieved curriculum.
- Developing strategies for using data to inform understanding of and approaches for ensuring curricular coherence as a district and in classrooms.
- Defining mathematical topic trajectory within and across grades and developing a process for analyzing instructional materials using this lens.
- Developing a process for analyzing the cognitive demand of the tasks as written in instructional materials and as implemented in classrooms.
- Developing understanding of how the system as a whole impacts curricular coherence, in particular policies and practices related to student opportunity to learn.
- Using findings on student learning to analyze and improve coherence in the intended and implemented curriculum and to align support structures for all students to be successful with important mathematics.
- Developing mathematics curriculum improvement plans, connected to the school improvement process for the ongoing refinement of the district’s mathematics curriculum.

The structure of the institute included meetings with all of the district leadership teams together, individual team meetings, and individual team meetings with a PROM/SE institute facilitator. The individual district team meetings were held between each facilitated meeting. Teams collected data and analyzed their intended (written curriculum and instructional materials) curriculum with respect to:

- Topic trajectories: concept and procedural development, definitions, representations, and the number of days of instruction per grade/course, noting redundancies and gaps.
- Levels of cognitive demand of tasks provided in the instructional and assessed materials.
- Course offerings and possible pathways through the K-12 district mathematics programs.
- Formal support systems available for students.

During team time, members also participated in structured classroom observations, noting how the curriculum was being implemented, reviewed state and local assessments and student achievement, and reviewed building and district policies related to student placement in specific courses and pathways through the mathematics program. Last, there were individual district team meetings with a PROM/SE institute facilitator. This structure allowed for each team to dig deep into their specific mathematics program issues with the support of an outside facilitator.

An important feature of the institute was its single mathematical topic approach to helping participants understand coherence. The development of student understanding of perimeter and area (measurement) were chosen as the topic of the institute because of the overall low achievement in these areas on PROM/SE assessments as well as state assessments. By narrowing participants focus and investigations they were able to make sense of the order and development of the two ideas trajectory, determine if there was a balance between the development of concepts and development of procedures, identify gaps and redundancy, as well as being able to note the depth and amount of mathematical thinking and reasoning students were being asked to engage in (cognitive demand) regarding these two ideas.

Participants also felt the educational research and best-practice articles were very helpful to their growth as leaders as well as gain a better understanding of what a coherent curriculum entailed. Throughout the institutes participants explored signs of a non-coherent and a coherent curriculum. Participants described a non-coherent curriculum as having a lack of explicit and shared learning trajectories within and across grades, and a series of non-connected activities with too many topics covered and little time to explore these in depth. Time spent on review and re-teaching at each grade level took away from teaching time devoted to new topics. And finally, limited opportunity to meet with other teachers and department heads resulted in a lack of communication within and across grades about content and topic trajectories.

The old saying, “All of us are smarter than one of us” was never more obvious then during the district leadership team’s curriculum coherence work. Yet, the make up of a team was critical. Without administrative support and involvement, without someone who knew where to go and how to get things moving within the district, nothing happened. And, without someone who knew mathematics, mathematics teaching, and student learning of mathematics - conversations were shallow and misguided. As district teams developed an understanding of coherence, they found ways to work together on improving their curriculum’s coherence as well as the mathematics program.

Focus on Leadership

The objective of PROM/SE capacity building was to prepare district leaders, administrators, and teachers to assume leadership in a variety of ways within their schools and district. Sessions focused on: 1) undertaking an examination of their curriculum (intended, implemented, and achieved) and instruction in mathematics and science; 2) identifying areas for improvement; 3) designing and implementing interventions to address these areas; and 4) monitoring and evaluating the results by collecting data to continue to inform and engage in the improvement cycle of study, reflect, plan, and implement.

Superintendent Summits

While PROM/SE focused mainly on providing professional development to teachers in its early years, the project also provided opportunities for professional growth for district superintendents. PROM/SE convened superintendents from participating districts in Michigan and Ohio for a series of summits to discuss how to utilize PROM/SE resources, superintendent leadership, professional development, and the importance of standards for defining a more coherent, focused, and rigorous curriculum. Bringing together superintendents from two states offered a rare opportunity for superintendents to share regional concerns and personal experiences in supporting mathematics and science efforts in their districts. Further discussions centered on the challenges facing districts in implementing state requirements and how PROM/SE and other resources could support districts facing these challenges.

Superintendents in the Classroom

Building from Richard Elmore's model and his work with superintendents in Connecticut, PROM/SE used the idea of shared classroom observations to deliver professional development for superintendents. The Superintendents in the Classroom Program was designed to build their capacity as instructional leaders by deepening their understanding of mathematics curriculum and instruction. The PROM/SE model differed in that it focused on only one area, mathematics, and classroom observation was for the entire lesson. Following each district/classrooms visitation and debriefing session, a professional development session followed that focused on an issue identified by the group.

Superintendents developed a common understanding of good mathematics curriculum, teaching, and learning, and developed the skills and knowledge to lead large-scale improvements in the teaching and learning of mathematics at the local level. Six superintendents participated from a Michigan county during the 2006-2007 school year. The following year the project expanded to twelve superintendents from two Michigan counties. In addition, the superintendents presented the project at the Michigan Association of School Administrators and received an award acknowledging their leadership efforts.

Lenses on Learning Institutes

Lenses on Learning Institutes were offered to PROM/SE districts for the development and support of building principals' and teacher leaders' mathematics knowledge and understanding of a quality mathematics program: curriculum, instruction, assessment, and issues of equity. PROM/SE staff led these institutes and supported local leaders in their facilitation of an institute, thus using this venue as a means to develop buildings-level capacity around mathematics leadership.

A Model for Coherence in Mathematics

PROM/SE convened a group of nationally recognized mathematicians early in the project to create a model for a coherent mathematics curriculum to guide future work in mathematics. This model was called the PROM/SE Coherence Model for Mathematics (PCMM) and initial attempts to assist school districts with creating coherent mathematics curricula used this model. However, during the summer of 2010 the National Governors Association and the Council of Chief State School Officers published the Common Core State Standards for Mathematics (CCSSM). The CCSSM provided a coherent structure for mathematics that was closely aligned to PCMM and was adopted by the vast majority of states. The CCSSM became the coherence model for PROM/SE's ongoing work in mathematics.

A Model for Coherence in Science

Science instruction in the U.S. has been very inconsistent with regard to content and rigor across classrooms, school districts and states. One of the reasons for this is the result of approaching the topics of science through the separate disciplines such as physics, chemistry, biology and earth science. The NSF asked PROM/SE to take the time necessary and to "start from scratch" in identifying a coherence model for science. PROM/SE assembled a team of nationally recognized scientists and science educators to address this issue. This team developed the "8+1 Fundamental Science Concepts", which provides a foundation for science education that is applicable across the science disciplines. The model and how it was developed is discussed in a later section.

PROM/SE in Action

In the Classroom: Maryville Public Schools

For two elementary teachers from the Maryville Public Schools system in Michigan, the PROM/SE Summer Mathematics Academy helped them see and understand math through the eyes of their students. After attending the summer academy and seriously examining the methods that they were using in their classrooms, the teachers felt that they could no longer teach within the math curriculum that had been used for the past seven years. Convinced that a format of math instruction that included mathematical thinking, problem solving, and students explaining solutions would lead to deeper mathematical understanding for their young students, they met with the principal and district administrators before the new school year to discuss implementing a new program of instruction. In just a short time, results are being seen in the classroom. Students are understanding and making connections with the math concepts being taught, and are having deeper mathematical conversations about the problems. One teacher remarked that she is helping her students solve problems rather than just get the answer. She hopes that this problem-solving attitude developed in second grade will be a foundation of deeper math understanding in future grades. She credited the intense training received through PROM/SE with helping her understand the impact of a student-oriented teaching style.



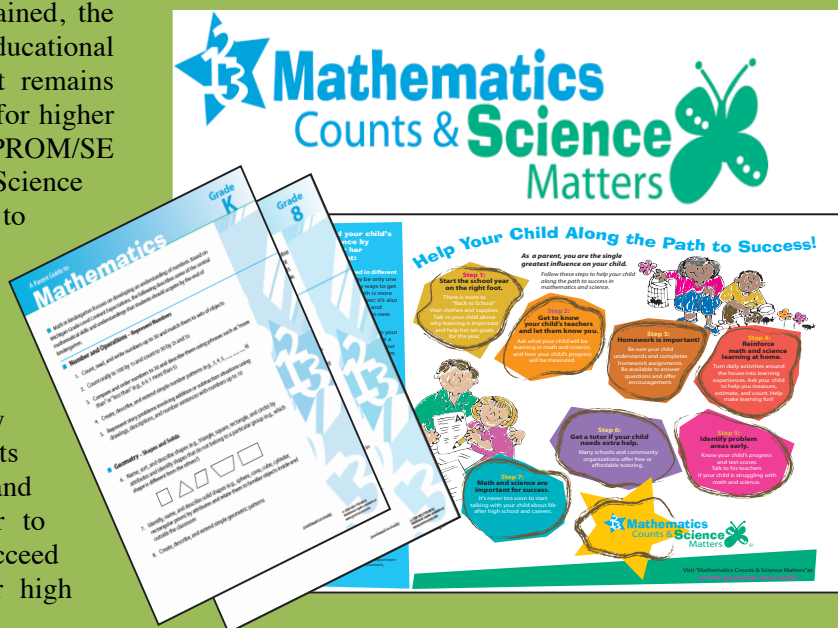
In the District: Lakeview School District



The Lakeview School District in Battle Creek, Michigan undertook a three-year process of transforming their principals from managers to educational leaders and PROM/SE was a part of this plan. Principals learned to be content experts and explored ways to conduct observations with dialogue centered on teacher growth. With this goal in mind, Lakeview's assistant superintendent for instruction asked the principals to attend the Education Development Center-based Lenses on Learning, a resource offered to the district through PROM/SE. Some principals were more open to the process than others, but the assistant superintendent pressed all to attend. After only one session, the principals saw new ways to dialog about good mathematics instruction. As the course drew to a close, the principals were enthusiastic about the potential to impact mathematics instruction. Lakeview's middle school principal shared what he learned by holding monthly meetings with the school's mathematics teachers.

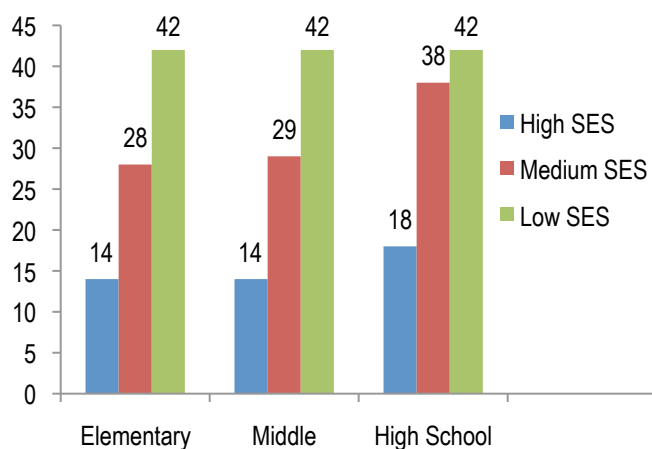
In the Community: Empowering Parents

No matter how well teachers are trained, the curriculum aligned, or how much educational research is funded, parental support remains vital in motivating children to reach for higher goals in their schooling and life. PROM/SE launched “Mathematics Counts & Science Matters” as an outreach program to parents of children in grades K-8. The program encouraged parents to raise their expectations for their child’s learning in mathematics and science, and armed parents with tools to help them along the way. By laying a solid foundation for students in earlier grades, parents, schools and community groups worked together to encourage students to take on and succeed in higher-level courses during their high school and college careers.



According to the U.S. Department of Labor, the fastest growing occupations require a strong knowledge of mathematics and science and 83% people holding higher salary jobs took math courses such as Algebra II or higher in high school, startling facts not overlooked by parents. “In surveying over 2000 household with school age children, we found that most parents, especially those in lower income households, understood the cause and effect of poor schooling on their child’s future,” stated William Schmidt, principal investigator. “However, we also found that lower income parents did not know where to get extra help if their child was struggling with math, or how to work with the school to ensure their child took higher level courses.”

Figure 6. Percentage of parents who think the child’s math program is doing a fair or poor job at preparing the child for future mathematics



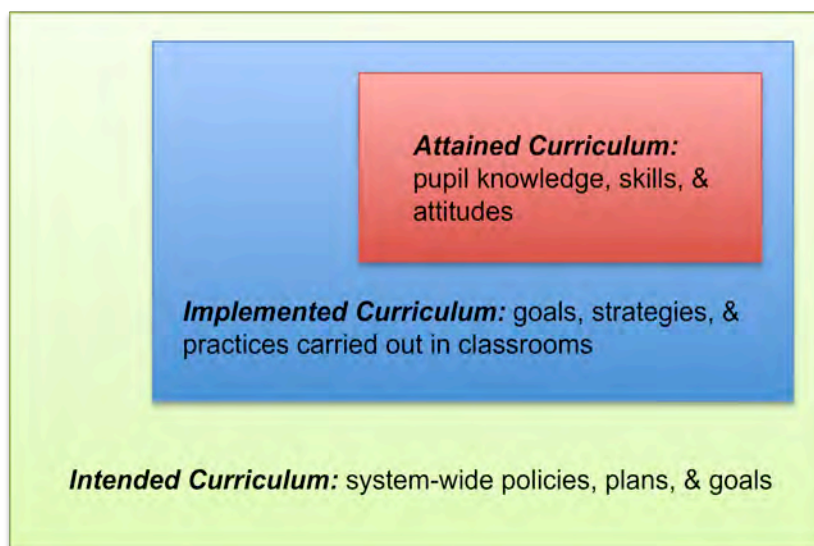
Teams of K-8 teachers, parents and MSU mathematics educators developed grade-level parent guides to highlighted the fundamental concepts each child should master. These guides serve as a quick reference and a useful tool in speaking to teachers on areas where their child struggle. To instill the importance of mathematics and science education, teams of parent volunteers identified local resources and after school programs, which they shared through community presentations.

CHAPTER 4 / What We Learned

Methods: Three instantiations of Curriculum

The tri-partite model of curriculum (Figure 7) that has been employed in many studies sponsored by the International Association for the Evaluation of Educational Achievement (IEA) since the First International Mathematics Study (1960s) (Travers & Westbury, 1989) provided the conceptual basis for the instruments used in PROM/SE. The IEA tri-partite curriculum model defines curriculum at three different levels: the *Intended* – what a system intends students to study and learn; the *Implemented* – what is taught in classrooms; and the *Attained* – what students are able to demonstrate that they know. Using these instruments provided a triangularization on what was happening with respect to mathematics and science within a district and enabled teachers, curriculum experts, and administrators to construct informed plans to improve student learning in mathematics and the sciences.

Figure 7. IEA Tri-Partite Model of Curriculum



For each curricular aspect, a comprehensive portrait of curriculum created by these instruments was reported to districts. District portraits were compared to international benchmarks from the 1995 TIMSS. The TIMSS Curriculum Frameworks were employed to measure the curriculum at these different levels. Thus, comparisons could be made not only with respect to international benchmarks for each level at which curriculum was measured, i.e., system/district (*Intended*), classroom (*Implemented*), and student (*Attained*), but we could also examine meaningful relationships among the levels for any particular district.

To measure curriculum at the district (*Intended*) level, curriculum experts completed a district ‘Road Map’. To complete this instrument, experts indicated at which grade(s) a topic was intended to be taught according to the district’s curriculum standards. Measurement of the *Implemented* curriculum was obtained by asking teachers to indicate how many lessons they devoted to teaching each topic in an exhaustive list of school topics in mathematics or science. Results from student assessments (*Attained*) were reported according to TIMSS Curriculum Frameworks categories. This multi-faceted report on districts’ curriculum provided an unprecedented portrait. Relationships between all three levels could be

explored within any particular year. More importantly, these relationships could also be explored across all the years of schooling. Based on data related to all three curricular instantiations, the learning trajectories for any particular topic could be identified. Examining learning trajectories involves asking such questions as “When is a topic first taught?” “What is gained by teaching this topic over so many years?” and “How can greater focus and coherence be brought to the elementary mathematics curriculum?” As instructional time is a finite resource, such questions are useful to develop a focused and coherent framework in which teachers may develop of coherent and challenging lessons.

In the words of its National Advisory Committee, PROM/SE has designed and assembled an extensive and unprecedented set of data including: highly curriculum-sensitive baseline information related to student learning; teacher measures of knowledge; measures of instructional time allocated to various topics; and coded district standards that are organized to provide useful information to participating schools and districts. This database was built from the administration of instruments over several years, including:

1. Student Assessments in Mathematics and Science, Grades 3-12

Blueprints created by national experts, mathematicians and scientists, mathematics and science educators from Michigan State University were used to design and construct the form. Upon recommendation from a team of psychometricians experienced in large-scale assessments such as the ACT, NAEP, and TIMSS, a duplex design described by Bock and Mislevy (1988) was adopted. Fifteen parallel forms were designed for both mathematics and science for each of the three grade levels: one for students in grades 3-5; a second for students in grades 6-8; and a third for students in grades 9-12. Some items were taken from existing item pools that had been used for some state assessments, NAEP, and TIMSS. To provide international benchmarks and linkages a substantial portion of items from the 1995 TIMSS were included in all three assessments. The item pool for mathematics contained over 1,300 items representing 22 distinct strands (topics) for the 3-5 grade band, 26 distinct strands for the 6-8 grade band, and 27 topic strands for the high school level assessment. The science item pool, developed similarly, consisted of over 640 items that represented 11-12 topic strands.

2. Student Background and Response Booklet, Grades 3-12

All students recorded their answers to the mathematics and science assessments in a machine-scored answer booklet. Also included in this booklet were selected background items from the 1995 TIMSS Student Background Questionnaire. The items were used to create a socio-economic indicator used in multilevel hierarchical analyses of TIMSS data (Schmidt et al., 2001). Other selected items from TIMSS asked students about their motivation in mathematics and science. For high school students, it asked how much education they intended to pursue.

3. Teachers’ Background Survey

Based on portions of the 1995 TIMSS Teacher Questionnaire, this survey contained items that addressed teachers’ academic preparation, professional certification, professional experience, classroom instructional practices and expectations, teachers’ experiences with professional development, subject matter pedagogical knowledge, and sense of readiness for teaching particular areas of mathematics and science. All mathematics and science teachers were administered this survey.

4. Teachers’ Content Goals Instrument

This instrument asked teachers to indicate the number of lessons when they taught specific mathematics or science topics. The instrument was available for teachers of grades 3-12 to complete as a web survey. A paper-and-pencil version was also made available for those who had difficulty accessing the web. Teachers responded to a list of topics that was exhaustive of school mathematics

or science topics as represented by the TIMSS Curriculum Frameworks for Mathematics and Science (Survey of Mathematics and Science Opportunities, 1992a, 1992b). The present survey was a revision of the 1995 TIMSS version that demonstrated significant relationships with student learning in analyses of the 1995 TIMSS (Schmidt et al., 2001).

5. Principal Questionnaire

The Principal Questionnaire was sent to schools at the same time as the student assessments. It contained items designed to assess the school context in which mathematics and science classroom instruction occurs and to determine the professional activities of school principals. It was a substantially shortened version of the 1995 TIMSS School Questionnaire.

6. Mathematics Associate Survey

Associates completed a survey about their beliefs and attitudes towards mathematics, the teaching and learning of mathematics, professional development, and professional leadership. This instrument was created for use with teachers participating in PCMI for which William Schmidt is an evaluator.

7. Mathematics Knowledge for Teaching Survey

Associates completed the survey that indicated their specific knowledge needed for the teaching of mathematics. The elementary and middle school versions were forms developed by the Study for Instructional Improvement (Rowan, Schilling, Ball & Miller, 2001). The high school version consisted of pilot items developed to extend the work of SII into high school. These items were developed through a cooperative effort with the NSF-funded international research project led by William Schmidt that investigated the preparation of middle school mathematics teachers and the NSF-funded project directed by Joan Ferrini-Mundy that investigated the knowledge required for the teaching of algebra. Two, two-day meetings were held with mathematicians and mathematics educators to develop a conceptual framework for the development of items and to identify the “Big Ideas” in mathematics that under gird middle and high school mathematics. Items were written by members of the international teacher preparation project in East Lansing and were reviewed and revised by MSU-affiliated mathematicians and mathematics educators.

8. District Roadmap

This instrument was completed by each district and district personnel most knowledgeable supplied answers to each section. Items addressed the following:

- demographics
- policies and budget related to mathematics and science instruction
- course offerings
- textbooks use and adoption
- technical resources, and
- the professional development of teachers.

Specific items were suggested by the Participation Questionnaire used in the 1995 TIMSS and reports from Consortium on Chicago School Research (Newmann, Smith, Allensworth, & Bryk, 2001).

9. Topic Trace Map

The Topic Trace Map methodology employed in the 1995 TIMSS was adapted for use with PROM/SE districts (SMSO, 1995). Curriculum specialists in each district were asked to indicate which topics were intended to be taught at which grade(s). Separate files were created for mathematics and science. This indication of the intended curriculum demonstrated significant relationships with both teaching time and student learning in analyses of the 1995 TIMSS (Schmidt et al., 2001).

The data collection process was conducted through use of a pre-formatted Excel spreadsheet. All of the information from teachers, and from state and district standards was coded according to a common framework that allowed for sophisticated analysis of alignment with international standards – all of which was reported back to the districts.

10. The PROM/SE District Contact Summit Needs Assessment Survey

The Goal of the Needs Assessment was to learn about the particular needs in mathematics and science as perceived by the district contacts, and to look for ways to connect to the PROM/SE activities.

Throughout the project at regular intervals, approximately 204,000 students in grades 3-12 in 587 schools were administered assessments in mathematics and science. Teacher background and content topic coverage data were obtained from 6,500 teachers. With this grain size of measurement, PROM/SE was able to generate reports that focused on student performance on each of the strands. Such reports provided participating schools and districts with curriculum-specific information that could be used in professional development.

Baseline Findings

Analysis of the wealth of data collected in the first year of the PROM/SE project underscores both the importance of a rigorous, coherent, and focused curriculum and how far many U.S. school districts are from meeting that standard. Information collected for the 2004 school year indicates that the schools selected to participate in the PROM/SE project exhibited many of the same difficulties demonstrated by the U.S. as a whole in previous research like the TIMSS. First, the *intended curriculum* of the districts failed to meet the benchmark set by higher-performing countries in either math or science. As demonstrated in Figure 8 the state mathematics standards in Michigan and Ohio that were in place in 2004 did not align very well with the topic-grade placement of those countries with the highest math achievement on the TIMSS. District-level intended coverage of topics also matched up poorly with international benchmarks (see Figure 9). Like state standards, district intended curricula covered many topics years too early and repeated other topics for far too many grades in succession.

Figure 8. Math Topics Intended in State Standards

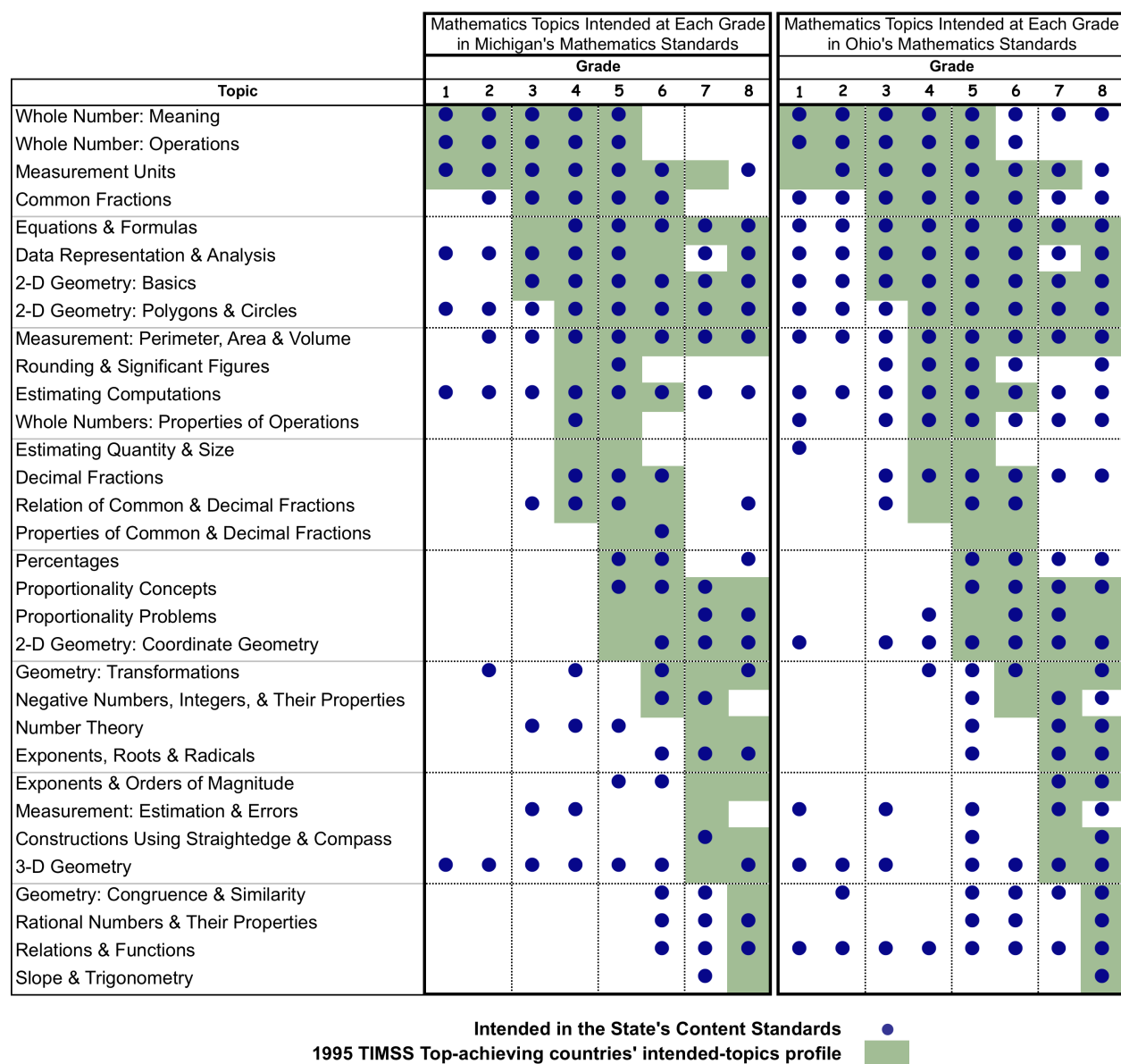
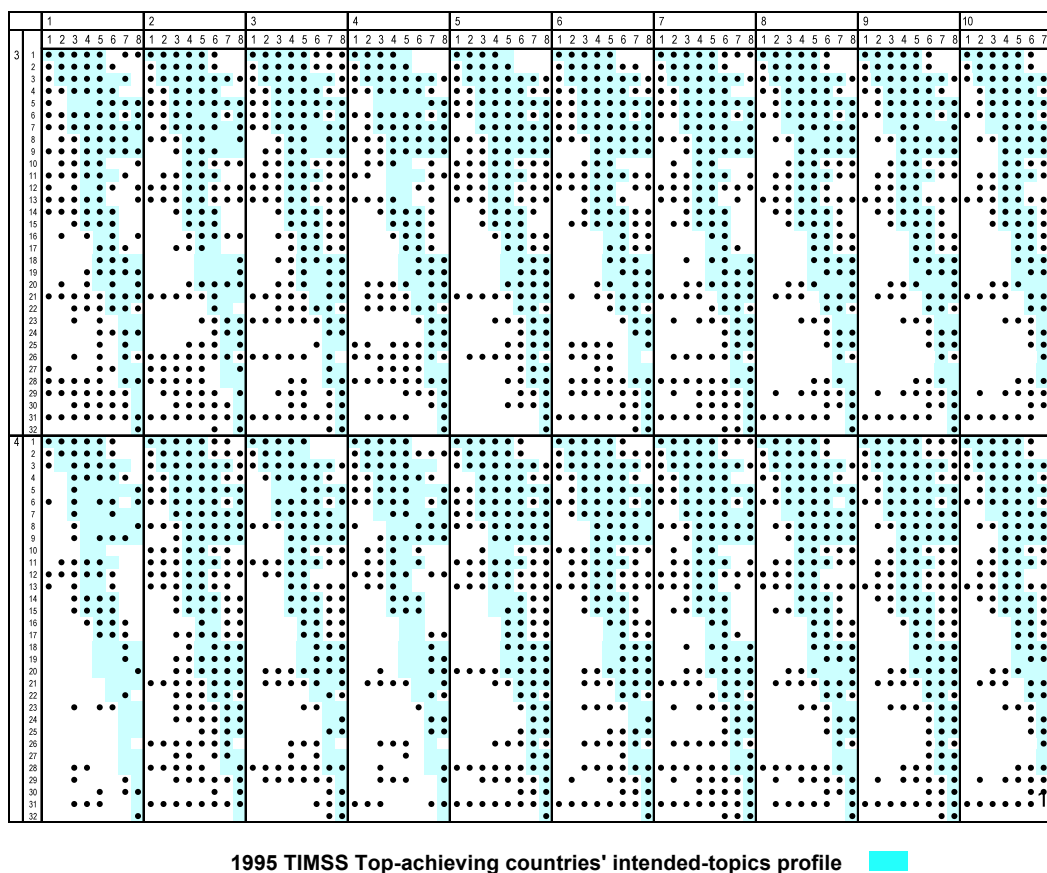


Figure 9. Intended Mathematics Curriculum (2003-2004) for PROM/SE Districts



The baseline data reveals not just the mediocre quality of the curriculum, but also profound inequalities in content coverage. Surveys of teacher's content coverage indicate that there were substantial variations in the rigor of content offered to students. Using the International Grade Placement (IGP) metric, a measure of content rigor based on the TIMSS benchmark of the highest-achieving countries, the PROM/SE research team found that the rigor of content ranged between two and *seven* grade levels across districts. These gaps were substantially larger in math than in science. In mathematics the largest inter-district variation occurring in sixth grade, a critical transition point from basic elementary topics to more advanced concepts. In science the variation in content offered to students increased dramatically in the middle grades, from roughly one grade level to two grade levels.

The 2004 PROM/SE baseline data also yields important insights on the contributors to socioeconomic and racial achievement gaps. The variation in content coverage is by no means random across types of districts. Students in high poverty schools and/or with a large percentage of minority students are consistently exposed to less rigorous math content than their peers in more advantaged districts. In fact, low-SES districts exhibited much less variation in content coverage than other districts. This relationship holds even across states, with students in low-income districts receiving the same (weak) content coverage whether in Michigan or Ohio, despite the two states' very different content standards. Content coverage for students in disadvantaged districts has more in common with similar students in other states than with students from different backgrounds in their own state. The strong relationship between SES and content rigor is of particular importance when we realize that the relationship is a systematic one that holds across grades. If variations in content coverage were effectively random, i.e. if a student was

exposed to less rigorous instruction in 4th grade but had a stronger curriculum in 5th grade, we might hope that the deficiencies in one year would be made up in later years. Unfortunately this more optimistic scenario finds little support in the data. Students in high-poverty, high-minority districts tend to receive persistently weaker content coverage across grade levels, causing them to fall ever further behind. In short, status quo of implemented curriculum appears to reinforce achievement gaps.

The traditionally weak and fragmented U.S. curriculum, and the inequalities in opportunity to learn rigorous content, are not without consequences. Consistent with previous research on the influence of content rigor on student achievement (Schmidt et al., 2011), the PROM/SE baseline data indicates that content rigor has a direct effect on student achievement. Figure 10 demonstrates the clear link between district content coverage (according to the IGP index) and a district's average student achievement in 8th grade mathematics. Content rigor has a similar effect on eighth grade science achievement, even controlling for a student's previous academic performance and socioeconomic status (Table 1). The PROM/SE data therefore provides powerful evidence that the failure to provide a high-quality curriculum to every student has resulted in poor performance in the aggregating while limiting the life prospects of less advantaged children.

Figure 10. Grade 8 Student Achievement vs Grade Placement of Curriculum Content

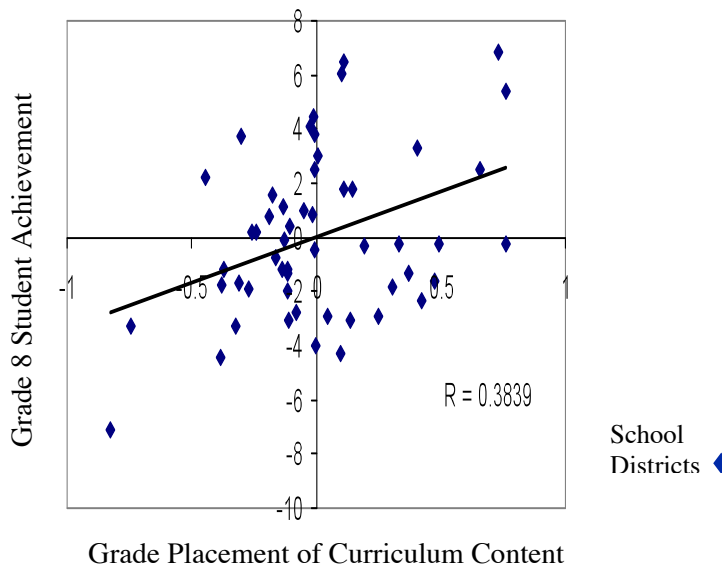


Table 1. District's Mean Grade 8 Achievement Predicted by 7th Grade Achievement, 8th Grade Science Class Rigor, and District Average Socio-economic Status (Analysis of Co-variance)

Summary of Predicting Variables in Model

Variable	Estimated Effect of Variable	Significance of Estimated Effect
7 th Grade Achievement	0.58	0.0001
8 th Grade Class Rigor	1.75	0.02
District Level Socio-Economic Status (SES)	1.56	0.01

Model Fit: Degrees of Freedom (3, 34); Variance Explained (R-squared), 0.81; Significance, <.0001.

A great deal of contemporary discussion on the topic of education reform has focused on the role of teachers and the potential for improving student achievement by improving teacher quality. The PROM/SE data suggests that teachers do indeed play a powerful role in shaping student outcomes. Statistical analysis of variations in content coverage indicates that they are driven chiefly by differences between classrooms, rather than between schools and districts. As the principal means by which content is delivered to students, teachers play a major role in determining what topics are covered, in what order, and how effectively. This fact makes a well-prepared teacher force an essential ingredient in creating a coherent curriculum. Regrettably, the PROM/SE baseline data suggests that teachers are by no means adequately prepared to lead their students in the learning of more rigorous mathematics and science content. Surveys indicate that very few elementary **OR** middle school teachers have a background in mathematics or science. This lack of preparation likely has serious consequences for student learning, as teachers without a math or science background both scored more lowly on the PROM/SE assessments of math and science knowledge and exhibited less confidence to teach demanding topics. Tables 2 and 3 display results for math teachers. The results for science teachers were very similar but are not displayed.

Table 2. Average Percent Correct on Mathematics Knowledge for Teaching Items (Three Separate Tests for Teachers of Grades K-6, 6-8, 9-12)

Grade Level Taught	Math Major	Math Minor	No Math Specialization
K-4	67%	61%	49%
5-6	70%	74%	55%
6-8	74%	69%	47%
9-12	74%	70%	64%

Table 3. Mathematics Teacher Preparedness- Self Reported

Grade Level Taught	Degree	% of Teachers with Degree	% of Teachers Confident to Teach All Topics	Mean % of Topics Teachers Say They're Prepared to Teach
K-4	Math major	0.4	27	74
	Math minor	3.0	20	74
	No math specialization	96.6	11	63
5-6	Math major	0.9	40	93
	Math minor	7.2	20	82
	No math specialization	91.5	11	70
6-8	Math major	12.3	26	87
	Math minor	19.3	23	81
	No math specialization	68.5	8	59
9-12	Math major	42.6	37	90
	Math minor	25.5	27	87
	No math specialization	31.8	26	81

Fostering Coherence in Mathematics

The PROM/SE team worked at multiple levels (teachers, principals, curriculum directors, and superintendents) to foster a better understanding of curriculum coherence and the connection between coherence and positive student outcomes. To articulate the PROM/SE model of curriculum change the project initially focused on mathematics. Previous research data from TIMSS studies, especially the mathematics curriculum profiles of high achieving countries, were integral to the development of these coherent standards. Schmidt, Wang and McKnight (2005) “define content standards, in the aggregate to be coherent if they are articulated over time as a sequence of topics and performances consistent with the logical and, if appropriate, hierarchical nature of the disciplinary content from which the subject-matter derives.”

Beginning in fall 2004 evidence-based PD was offered for mathematics teachers. The twin foci for the initial PD efforts were: use of PROM/SE baseline data to inform instruction, and deepening of teachers’ mathematics content knowledge, especially related to issues of coherence. For the PROM/SE Teacher Associates, eight mathematics institutes were offered during the school year between 2004 and 2007, and summer academies that focused on mathematics content were offered for PROM/SE Associates and other teachers from participating school districts in 2005 and 2006. Additionally, Lesson Lab was contracted to offer on-line training in 2005 and 2006 for facilitators and PROM/SE Associates, respectively.

In keeping with the project goal of establishing a base of empirical evidence to direct curriculum reform, a randomized field study developed to assess the value of both micro (within a grade level) and macro (across grades) coherence-capacity building was initiated during year three (2005-2006) of the project. The main purpose of the capacity building work was to improve teachers’ and district curriculum specialists’ mathematics knowledge, with particular focus on the kind of mathematical knowledge needed for making “curricular coherence” central to the work of teachers. Districts were randomly assigned to the three treatments defining a 2X2X2 design. For micro coherence this represented an extension of what was done for all districts during the first two years, but an entirely new line of capacity building was provided at the macro level. Three design factors were defined for the study: (A) coherent curriculum-focused professional development (micro coherence); (B) curricular trajectory-focused work with district teams (macro coherence); and (C) use of PROM/SE data resources to support curricular change.

PROM/SE worked on building a shared understanding of coherence in mathematics with teachers and curriculum specialists from all districts during the first two years of the project and with half of the districts in the following three years. During the third year, PROM/SE developed and implemented a more advanced level of capacity building related to micro curricular coherence. We also concentrated on coherence with district staff at the macro level (curriculum directors, administrators and teachers).

Preliminary data indicates that the effort to foster a more coherent curriculum in the PROM/SE districts was successful. Between 2004 and 2010 the focus of instruction in PROM/SE districts changed considerably. A comparison of the distribution of time allotted to the three general mathematics categories mentioned above (basic, transitional, and algebra) in 2004 and 2010 shows a major change in the average time teachers dedicated to these topics at each grade level (see Figures 11 and 12). In 2004 teachers spent the bulk of Grades 1-4 on basic math, gradually increasing the proportion of time devoted to transitional math, which peaked in Grade 7 before declining. The proportion of instruction dedicated to algebra rose steadily over the eight grades. By the end of middle school teachers were spending roughly a third of their time on Algebra, while still using 15% of their time on transitional math topics. Figure 9 shows a strikingly different pattern. By 2010, teachers were spending much more of the first few grades on basic mathematics, and introducing transitional math in a much more focused way, peaking two grades earlier than previously. The peaks in each category were greater than before as well: teachers used nearly 45% of their instructional time in Grade 1 on basic math (compared with under 40%), and almost 40% of their time on transitional math in Grade 5 (compared with 30% in Grade 7). In addition, not only did

teachers cover transitional math in a more concentrated way and in an earlier grade, but they also shifted more quickly towards algebra topics. In 2004 teachers spent 30% of their time in Grade 7 and 35% of their time in Grade 8 on algebra. By 2010 this had increased to 35% in Grade 7 and over 45% in Grade 8. In addition, the variation in content coverage across districts declined between 2004 and 2010. The implemented mathematics curricula in PROM/SE districts were much similar to one another near the end of the project than at the beginning. All of these developments point towards a more coherent curriculum.

Figure 11. Math Coverage 2004

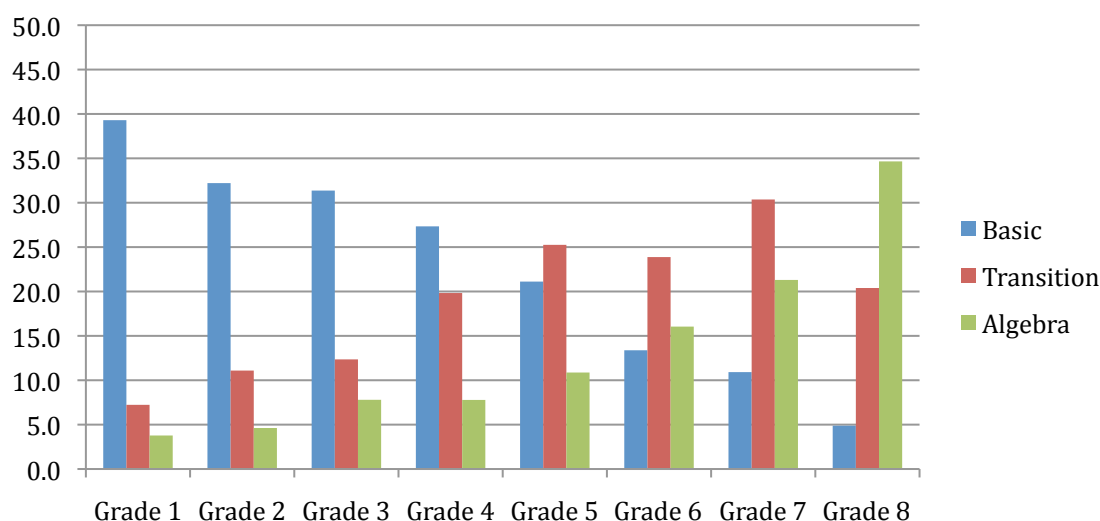
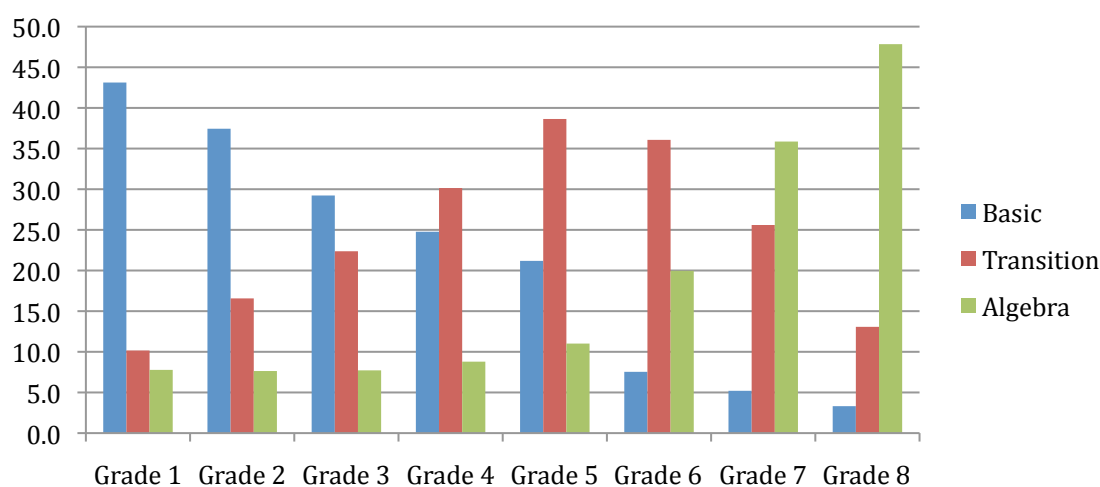


Figure 12. Math Coverage 2010



At the same time that the mathematics curriculum was becoming more coherent, student achievement on the PROM/SE mathematics assessment was improving. Average district scores on the PROM/SE mathematics assessment increased between 2004 and 2010 both overall and in each of three general categories: basic math, transitional math, and algebra. It is critical to note that reducing the focus on basic math after grade 4 and the quicker shift to transitional (and later, algebra) math topics did not prove to be

too much for children to learn. When presented with a more challenging curriculum, students in PROM/SE districts rose to the occasion.

Students also registered gains in specific content strands. Data analyses indicated changes both in terms of curricular coverage and of achievement gains from the base year 2004 to 2008. Achievement gains were measured in each of the more than 20 subtest strands, depending on grade level. Both types of data were relevant as our model suggested that curricular reform would bring about changes in the curriculum coherence itself and that in turn would impact learning. Evidence of causal effects was difficult to establish in field-based studies such as this. Nonetheless the different types of evidence available produced a consistent pattern, which signified that the work on curricular coherence in mathematics was strongly related to improved student learning.

The topic foci were: fractions; decimals and percents; whole numbers, including operations and place value; measurement units; geometry (especially angles); and perimeter and area. Of the six topic areas, all but one showed statistically significant gains in achievement on the relevant subtest, in at least one of the three grades, from 2004–2008. The only topic that did not demonstrate significant gains was measurement units. The estimated effect sizes were very respectable, ranging from .2 to .7 of a standard deviation. The geometry area had among the largest gains, e.g., .65 of a standard deviation gain in measures of angles at the fifth grade. That topic was a strong focus area, especially in our summer academies.

The middle school work focused on five topics: fractions; decimals and percents; perimeter, area and volume; number theory; and linear algebra. All except number theory had significant gains in all three middle grades (6–8), from .27 to .49 of a standard deviation.

Achievement gains across all the more than 20 subtests provided an important comparison. The specific topic areas on which PROM/SE focused, demonstrated large estimated effect sizes, whereas the average effect size estimated over all the subtest areas measured at the elementary and middle school levels was .13 and .14 respectively (not statistically significant for most other subtests). Thus we found relatively significant gains in the topic areas related to our coherence work; this was not the case across all subtest areas, especially those that were not the focus of PROM/SE PD. Further supporting evidence came from the lack of any improvement at the high school level. Although we tried diligently to include high school teachers in the work, this was met with little success and the rates of attendance were very low. Not surprisingly there were virtually no significant gains in mathematics achievement at the high school level.

The randomized experiment was designed to address the question of whether such capacity building activity around coherence was effective in improving student learning. The preliminary results were mixed. In some areas the achievement gains were statistically different for those districts that received additional capacity building. This was true for fractions at the third grade ($p < .03$ for the micro level and $p < .04$ for the macro level). In some cases the gains were attributable to the micro and/or the macro coherence, but for other subtest areas the effects were interactive in nature (such as word problems with fractions $p < .05$ and ordering fractions $p < .008$). For ordering fractions at the fourth grade, the biggest gains occurred for those districts with the macro training ($p < .02$). Similarly there were many significant differences in gains at grades six and seven, especially related to the algebra subtests (a major focus topic in the middle grades), but this was not the case at eighth grade.

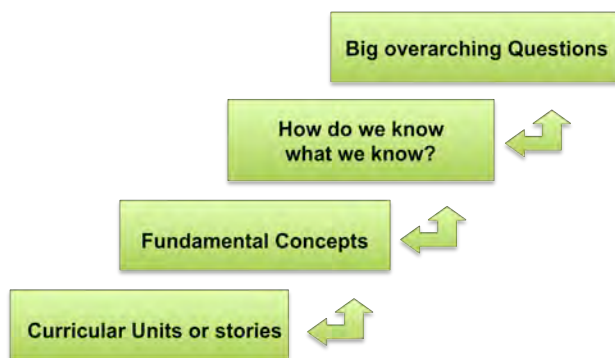
Developing A New Framework for Science

Unlike mathematics, science lacks a straightforward hierarchical structure to guide the creation of a coherent curriculum. Consequently, whereas in mathematics the PROM/SE team was able to move fairly quickly to facilitate the move to a more coherent curriculum, their work in science was devoted to creating a framework for teaching science. To articulate the framework for a coherent curriculum for K–8 science, PROM/SE identified a group of nationally renowned science experts that included bench

scientists, science educators and science leaders. Members are listed at the end of this section. This group initially met in 2006 as part of “Science Education in the 21st Century: A PROM/SE Forum” and were charged with identifying the overriding scientific themes that lend coherence to the science curriculum. The goal was not to develop new standards, nor new instructional materials, as good materials were available and the work of AAAS and NRC in developing standards was thorough. What was needed to provide coherence was the logic or “glue” which held science instruction together and made it more than a series of isolated facts or experiences. Additional meetings were convened by PROM/SE to solicit input from this group. In these discussions the science panel addressed broad concepts that transcend disciplinary structures and grade levels and worked to identify specific ideas that are considered fundamental to the learning and understanding of science for the twenty-first century.

Figure 13 is a flowchart that summarizes the discussions of the PROM/SE Science Panel that focused on the relationship between school-based science units and a set of fundamental concepts or “big ideas” that can help organize the science curriculum. Underlying all of science, and uniting science as a discipline, is the question: “How do we know what we know?” Every explanation in science is subject to the scrutiny of this question, which must be answered with reference to natural phenomena. The Science Panel defined fundamental concepts as the most basic form of natural phenomena. They provide conceptual coherence to the curricular units that characterize the developmentally-appropriate science learning progressions across the grade levels.

Figure 13. Science Model for Curriculum Coherence



Science was defined here as the search to answer the big overarching questions, such as “Where/how did life evolve and how did the universe (solar system, planets, stars, etc.) come into being?” with reference to natural phenomena. Underlying the entire framework was a working definition of science:

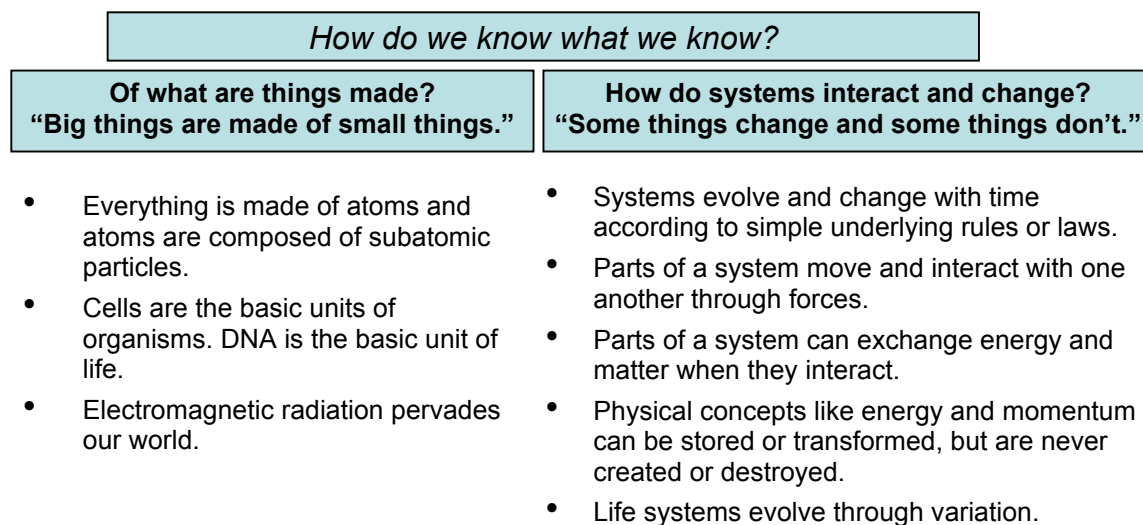
Science is a human enterprise that seeks to explain the way the natural world works by means of a small number of laws of nature. These laws, often expressed mathematically, are explored using tools such as experimentation, observation, measurement, and description. Information is synthesized into understanding through creative and logical thought, with theories and predictions continuously tested by observation, experimentation, quantitative measurement, and mathematical reasoning.

- Experiments are designed around an empirically falsifiable question.
- Observations and measurement have to be quantitative and reproducible with uncertainties that are quantifiable.
- Creative and logical thought includes critical, skeptical and often mathematics reasoning, informed by existing knowledge.
- If a phenomenon cannot be described by these criteria, it indeed lies outside the purview of science, and is not science.

The Science Panel chose to use the term “stories” to describe what are commonly referred to as science units for instructional purposes. For example, the life cycle of a butterfly would be a science “story.” The term story was used to denote that these stories related some specifics about the natural world but also, as good literature does, communicated something deeper that transcended the specifics. The science stories or units were the functional level at which student understanding of science was developed. They varied by district and the challenge for science education was to link the stories to the overarching fundamental concepts. The conceptual basis for science curricular coherence was in the teaching of the fundamental concepts through the stories as the foundation for science instruction. Thus, regardless of the stories or units that a district chooses, understanding in terms of the fundamental concepts should be common to all. Coherence for school science was thus defined differently than it is for school mathematics and implied the need for a different approach.

The eight fundamental concepts that form the foundation of the PROM/SE science framework are listed in Figure 14. The Science Panel also identified “inquiry,” representing the multiple process components of scientific investigation, as essential to all science.

Figure 14. 8+1 Fundamental Science Concepts



The fundamental concepts generated by the group were mapped against several state standards and the AAAS benchmarks to check their completeness. This was the initial step in integrating the experts’ work with actual science curricula/standards. The results suggested that these existing standards can be accommodated by the proposed framework. The Science Panels’ model was used in the design of the 2007-2008 PROM/SE science professional development event: “The Evolution of Everything.” Three topics, one from physical science, one from earth science, and one from biological science, were used to illustrate the fundamental concept that systems evolve: the Big Bang and the formation and evolution of the elements and matter up to the scale of planets; plate tectonics and the evolution of Earth; and organic evolution. All three are intimately connected and transcend disciplinary science boundaries, yet all refer back to the same fundamental concepts.

Our initial work in capacity building for science teachers centered on developing the new notion of science coherence using the concept of evolution as an illustration. (The final science framework evolved fully in fall 2008.) Thus, we expected little gain in terms of science achievement from 2004 to 2008, and indeed the longitudinal test results indicated virtually no gains in science achievement across the districts.

During year six the PROM/SE Science Framework was taken to the next level by having the Science Panel analyze the adequacy of the proposed framework by examining actual school district curricula. The new science framework was introduced to all of the PROM/SE partners and a methodology for reviewing and restructuring curriculum within the context of the framework was developed. Also during year six PROM/SE districts piloted, on a very limited basis, a methodology for reviewing and redesigning both science and mathematics curricula.

The PROM/SE Science Panel:

William Schmidt, PROM/SE Principal Investigator, College of Education, Michigan State University

George Leroi, PROM/SE Co-Principal Investigator, Department Of Chemistry and College Of Natural Science Dean (emeritus), Michigan State University

Simon Billinge, Department of Applied Physics and Applied Mathematics, Columbia University
Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory

Leon Lederman, Fermi National Accelerator Laboratory, Pritzker Professor of Physics, Illinois Institute of Technology (retired), and Nobel Prize recipient

Audrey Champagne, Department of Chemistry and School of Education (emeritus), University at Albany, State University of New York

Richard Hake, Department of Physics (emeritus), Indiana University

Paula Heron, Department of Physics, University of Washington

Lillian McDermott, Department of Physics, University of Washington

Fred Myers, Director of Science, Glastonbury Connecticut Public Schools

Roland Otto, Lawrence Berkeley National Laboratory (retired)

Jay Pasachoff, Department of Astronomy, Williams College

Carl Pennypacker, Lawrence Berkeley National Laboratory

George Viebranz, Ohio Mathematics and Science Coalition

Paul Williams, Department of Plant Pathology (emeritus), University of Wisconsin

The Filming of 8+1 Science

During several intensive days of filming at the Museum of Science and Industry in Chicago, a team of scientists, educators, film producers and PROM/SE staff created a short film on the fundamental concepts. The film, titled *8+1 Science*, explains this shift in thinking about how to teach science.



Scientists agree that pretty much everything can be attributed to these eight concepts. So, why isn't science taught this way in our schools? The film discusses this pressing question and why it is important to change the way science is currently taught.

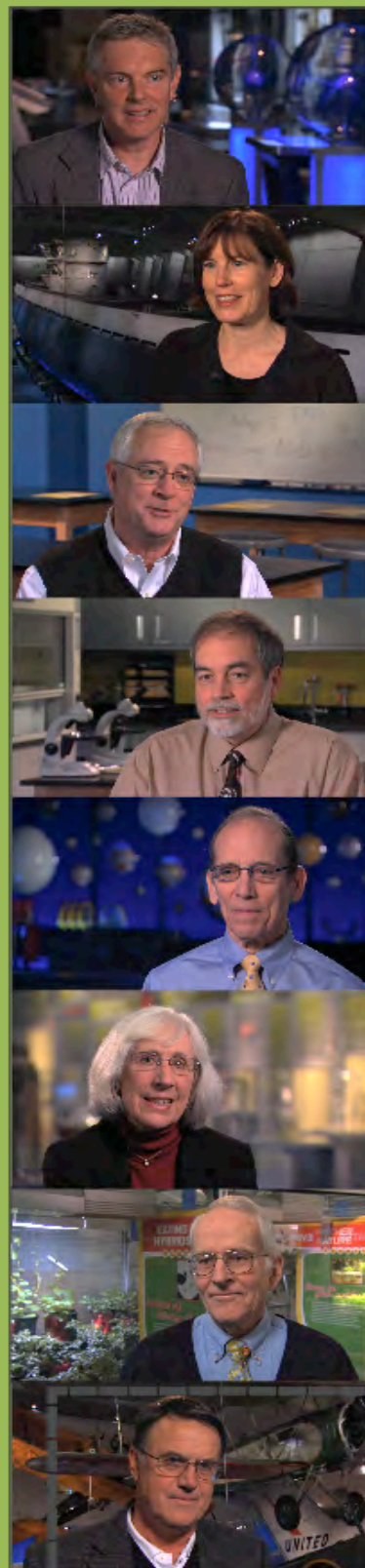
“Scientific discovery is moving at such a pace that in five years from now, even two years from now, there are going to be really important discoveries that have a huge impact on our lives and they weren't in our middle school curriculum,” stated Simon Billinge, science panel member and Professor of Applied Physics and Applied Mathematics at Columbia University. By teaching inquiry and developing student understanding of science that transcends disciplinary lines, teachers can help students develop critical thinking skills that go beyond simple memorization of facts.



The film also answers questions that school administrators, teachers, and policy makers may have when thinking about how to implement 8+1 Science in their district. “8+1 provides a way of thinking about the most important ideas in science and make these ideas coherent. Teachers can use these with any textbook or state standards,” said Fred Myers, Director of Science for Glastonbury Public Schools, Connecticut.

The project also produced a companion series of posters designed for elementary, middle and high school classrooms. The film and posters are available for download on www.promse.msu.edu.

Science Panel members featured in film pictured top to bottom: Simon Billinge, Paula Heron, David Chapin, Fred Myers, William Schmidt, Audrey Champagne, Paul Williams, Roland Otto



CHAPTER 5 / Summary of Accomplishments

- A. Coherence and its importance to reforming math and science education.** The primary theme of the PROM/SE grant was to build and deliver coherent mathematics and science curricula for participating school districts. The Third International Mathematics and Science Study (TIMSS) identified the lack of coherence in curriculum as the distinguishing difference between high achieving countries and the United States. Early in the PROM/SE implementation, teacher professional development (PD) in coherence and the analysis of post PD student achievement data reflected a strong positive correlation. PROM/SE worked with teachers and administrators to develop an understanding of how to identify, build and deliver coherent mathematics and science curricula.
- B. Coherence in mathematics is supported by the Common Core State Standards for Mathematics.** Mathematics is, by its very nature, a coherent discipline. Mathematics is comprised of logical progressions of topics, concepts and ideas that increase in scope and depth. It is necessary to build a deep understanding of the foundational concepts in order to reach the more advanced levels of the progressions. Unfortunately, many textbooks offer too many topics and do not necessarily present the topics in a logical progression. In order to help participating districts deliver a coherent mathematics curriculum, PROM/SE focused on professional development to help teachers build a deep understanding. This process was aided by the publication and adoption, by most states, of the Common Core State Standards for Mathematics (CCSSM). PROM/SE developed an on-line process for school districts to align their existing textbooks and materials to the CCSSM so that they can deliver a coherent mathematics curriculum immediately.
- C. Coherence in Science is Supported by the “8+1 Fundamental Science Concepts.”** Traditionally science has been taught as a grouping of almost unrelated topics and disciplines (e.g. biology, chemistry, physics, earth science, etc.). Unlike mathematics, science does not have an inherent logical structure that is coherent. The search for a coherent framework for science required extensive thought and work by a team of practicing scientists. The PROM/SE scientists began by identifying what they believed a scientifically literate high school graduate should know and be able to do. Having done that, the team identified eight fundamental science concepts that support scientific literacy and understanding across the science disciplines. The process of “inquiry” which is fundamental to all of science was added to the eight fundamental concepts resulting in the “8+1 Fundamental Science Concepts.” Working with teams of teachers in participating school districts, PROM/SE developed an on-line system for teachers to incorporate the “8+1 fundamental science concepts” into their science lessons. The aim was to create a learning atmosphere so that as the students progressed through the grades they developed continuously deeper understandings of the 8+1 fundamental concepts and the importance of the role of these concepts in all science disciplines. The overall goal was for students to develop a deeper understanding of science that went beyond what otherwise would appear to be a collection of isolated facts and formulas. The “8+1 Fundamental Science Concepts” were designed to be so basic that they support any grouping of science topics or content that may be identified in a set of science standards.

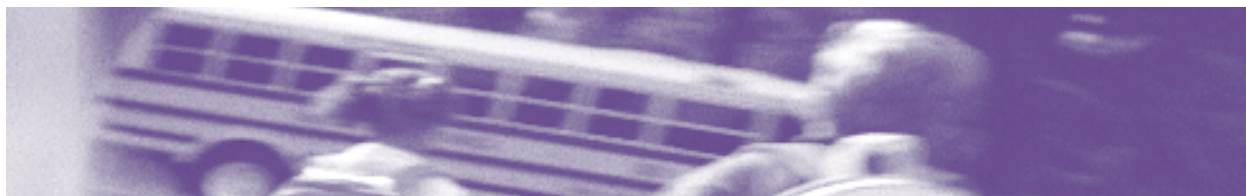


- D. Coherence in the Classroom is supported through Professional Development, utilizing textbooks and technology as resources.** Having identified a model for building coherence in mathematics (the Common Core State Standards for Mathematics) and a structure for building coherence in science (The “8+1 Fundamental Science Concepts”), PROM/SE focused on how to deliver coherent curricula to students. The PROM/SE three-pronged approach to the delivery included professional development for teachers and administrators, effective utilization of textbooks and resource materials, and the employment of technology. The professional development of administrators began with demonstrating the value, in terms of student learning and achievement, of a coherent curriculum and then of having them look for and recognize coherent instruction in their classrooms. The professional development for teachers was primarily on subject matter content and depth of understanding in both mathematics and science. The next step in delivering coherent curricula was to change the view that textbooks were the curriculum to a view that they were one of many resources to support the curriculum. Technology played a major role in supporting this changing role for the textbooks. For mathematics, teams of teachers outlined units and lessons on the PROM/SE on-line system that described a curriculum aligned to the Common Core State Standards for Mathematics. For science, the on-line units and lessons reflected enhanced science lessons that emphasized the role of the “8+1 Fundamental Science Concepts” and the relationships between science phenomena across disciplines. In both mathematics and science, the on-line curricula became a real time documentation of curricula that could change and improve based on teachers’ experiences and students’ learning.
- E. Research demonstrates the relationship of coherence to performance.** The results of the PROM/SE project underscored the lessons of international studies like TIMSS: that a coherent, focused curriculum plays a key role in promoting student achievement in mathematics and science. Rather than a disconnected series of topics, mathematics and science instruction must be conducted with a view to the underlying structure of the discipline, so that students do not just memorize facts but acquire a rich understanding of STEM content. The strong relationship between internationally-benchmark, coherent standards and student achievement across the PROM/SE districts pointed to the vital importance of adopting *and implementing* strong curriculum standards.
- F. Highly Refined Data on Student Achievement and Teacher Content Coverage is Desirable for Serious Reform.** The use of high-quality data to drive instruction and school reform has become somewhat commonplace in discussions of educational reform. The unique contribution of the PROM/SE project is that it identified a concrete means by which data can be used. Rather than treating the classroom as a black box, collecting data on content coverage can yield invaluable insights on actual instruction by teachers in order to target professional development, discover best practices, and evaluate the degree to which curricular standards were being implemented.
- G. Leadership around Coherence Makes the Difference for Local Reform.** Curricula do not implement themselves, nor are attempts to reform content standards self-enforcing. The success of PROM/SE in fostering a more coherent curriculum was based in large measure on the active commitment of superintendents, principals, and teachers. The PROM/SE project adopted a model of *system-wide* accountability in which school-level and central staff administrators acted as instructional leaders and teachers as empowered stakeholders – an approach that should serve as a standard for future reform efforts.

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Appendix

PROM/SE Research Report Summaries

The PROM/SE Research Report series highlights key findings from the PROM/SE data. Full reports can be viewed at <http://www.promse.msu.edu>.

Making the Grade: Fractions in Your Schools, vol 1, May 2006. Using PROM/SE student achievement data in seven subtest areas to highlight learning in grades 3-12, key findings emerging from the data show that large numbers of students are not learning foundational fractions such as equivalent fractions and common denominators, making later success in more advanced mathematics difficult. Further analysis found in the report suggests that third grade is a crucial time for teaching and learning foundational concepts.

Knowing Mathematics: What We Can Learn from Teachers, vol 2, Dec 2006. The report highlights data collected from over 4,100 K-12 teachers in nearly 60 participating school districts in Michigan and Ohio. PROM/SE surveyed K-12 mathematics teachers about their knowledge of mathematics for teaching and how they acquired it. Key findings reveal significant differences among grade bands and in participating districts in teachers' feelings of preparedness to teach nearly 50 mathematics topics. Data reveal that elementary and middle school teachers do not feel well prepared to teach higher math topics which most likely impacts their ability to lay critical foundations for their students' later, higher math success. Long-term and systematic solutions for K-12 districts, professional development, and teacher preparation programs are discussed. Key recommendations for districts are provided, including: recognizing that teachers need professional development that focuses on specific topics in the mathematics school curriculum to offer them a deep understanding of these topics; assigning the most mathematically sophisticated teachers to foundational high school courses such as first year algebra; and creating induction programs for beginning teachers that emphasize the teaching of specific mathematics content.

Dividing Opportunities: Tracking in High School Mathematics, vol 3, May 2008. This report examines the extent of tracking in mathematics courses in the 30 high schools that are part of PROM/SE. These schools represent over 14,000 seniors from nearly 18 districts. The report reveal startling facts: 1) PROM/SE districts offer an incredibly large number of distinct high school mathematics course titles and there is substantial variation across districts. The number of mathematics courses offered by districts varied from 10 to 58. 2) Analysis of the 14,000 students' course selections and the order in which they took these courses showed the number of sequences varies appreciably by district. There were over 200 distinct mathematics course sequences in some districts while in others there were less than 30. Most districts had closer to 60 sequences. 3) Though there are not overt curricular tracks, the large number and types of mathematics courses offered implies that many students are encountering wildly discrepant learning opportunities within and across districts.

Dividing Opportunities: Tracking in High School Science, vol 4, June 2008. This report examines the extent of tracking in science courses in the 30 high schools that are part of PROM/SE. These schools represent over 14,000 seniors from nearly 18 districts. Key report findings: 1) PROM/SE districts offer an incredibly large number of distinct high school science course titles and there is substantial variation across districts. The number of science courses offered by districts varied from 7 to 55. 2) Analysis of the 14,000 students' course selections and the order in which they took these courses showed the number of sequences varies appreciably by district. There were over 100 distinct science course sequences in some districts while in others there were closer to 50. 3) Though there are not overt curricular tracks, the large number and types of science courses offered implies that many students are encountering wildly discrepant learning opportunities within and across districts.

Variation Across Districts in Intended Topic Coverage: Mathematics, vol 5, March 2009. This report explores the extent to which implementing curriculum at the local level has created mathematics curriculum standards (grade level learning expectations) with vastly different learning expectations that in turn undermines any ‘intent’ to provide to all students an equal opportunity to learn mathematics. Given the cumulative nature of knowledge, especially in mathematics, differences in learning opportunities lost at a specific grade may not be gained at a later time. These disparities are not just experienced by children who live in poverty. This affects children who live in wealthy suburbs that surround urban areas as well. Data from across districts nationally are examined.

Opportunities to Learn in PROM/SE Classrooms: Teachers’ Reported Coverage of Mathematics Content, vol 6, April 2009. This report examines the pattern of reported mathematics content coverage in elementary grades classrooms in the PROM/SE districts. In these PROM/SE districts about 2625 teachers (about 525 teachers at each of the five grade levels) reported on their mathematics content coverage. Our results indicate that there is great variation across classrooms in the mathematics content coverage, suggesting the presence of enormous inequalities in opportunities to learn mathematics content. This surprising variability extends not only between districts but also across the hallway within the same school.

Content Coverage and the Role of Instructional Leadership, vol 7, June 2009. This study examines the variation in reported science content coverage among 53 PROM/SE districts in Michigan and Ohio. Variation is also described among schools within participating districts and among classrooms within the same school. Data point to extensive variation in the amount of time allocated to science instruction at district, school, and classroom levels across elementary and middle grades. In a subset of 5 adjacent school districts, striking variation is noted in coverage of topics addressed as compared to the science curriculum of high achieving TIMSS countries. Similarly notable variability is found in the number of instructional days devoted to science topics in schools within the same district and in classrooms within the same school. Findings reflect the importance of instructional leadership at all levels of the educational system to ensure that district intentions and school-level implementation are aligned in promoting coherent and consistent enactment of rigorous standards. The need for strong instructional leadership by district superintendents as well as building principals is discussed in detail.

Towards Coherence in Science Instruction: A Framework for Science Literacy, vol 8, October 2011. This report details a conceptual framework for building science literacy through utilizing the PROM/SE 8+1 fundamental science concepts. One of the most powerful ideas underlying science is that a small number of simple laws guide the behavior of the natural world. Yet, science is not taught this way in the schools. The report explores how students can be taught these laws utilizing the 8+1 framework and then shown how to apply these in different situations to gain understanding and new insight into natural systems.

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Participating School Districts

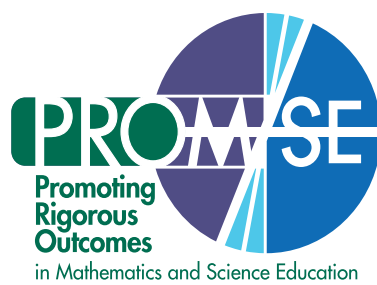
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