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ABSTRACT

Professional development allows prospective teachers to develop their professional skills in order to help students achieve higher standards. The need for more challenging mathematics content for students means that teachers will also have to learn more challenging mathematics content and how to teach it. This document suggests new ways of designing and implementing effective professional development to reach these goals for those who have some responsibility for designing or conducting professional development programs or initiatives. This publication may also be of interest to teachers selecting their own learning opportunities, evaluators interested in what to look for in effective programs, and funding sources that appreciate guidance in the kinds of programs that have the greatest likelihood of success. This publication is designed for anyone interested in "breaking set" with traditional schemes for professional development and exploring new designs for learning. It can be used to identify what works in professional development. While the strategies contained in Section I will help designers of professional development opportunities, they are included so that educators can identify elements of programs that will lead to new ways of teacher and student learning and improved student achievement. Strategies, additional resources, and the example programs all provide educators with a grounding in how to select programs and where to go for additional information. Section II provides a description of each strategy including the elements necessary for design and implementation along with issues for educators to consider. The discussion of each strategy concludes with a real-life example of the strategy in action. Section III features lengthier descriptions of existing programs that effectively combine several of the Strategies for Professional Development including programs honored in the U.S. Department of Education's National Awards Program for Model Professional Development. Section IV contains brief descriptive and contact information for organizations and professional development projects that are working to offer educators training and information. (ASK)

Ideas that Work

Mathematics [illegible] Development

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Ideas *that* Work: Mathematics Professional Development

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Effective Professional Development *for* Teachers of Mathematics

By Susan Loucks-Horsley

Professional development plays an essential role in successful education reform. Professional development serves as the bridge between where prospective and experienced educators are now and where they will need to be to meet the new challenges of guiding all *students in achieving to higher standards of learning and development (U.S. Department of Education, 1995, p. 2).*

The image of a bridge is useful for those who provide professional learning opportunities for mathematics teachers and others responsible for helping young people to learn the mathematics they will need for the 21st century. A bridge, like professional development, is a critical link between where one is and where one wants to be. A bridge that works in one place almost never works in another. Each bridge requires careful design that considers its purpose, who will use it, the conditions that exist at its anchor points (beginning, midway, and end), and the resources required to construct it. Similarly, each professional development program or initiative requires a careful and unique design to best meet the needs of the teachers and the students to be served.

The current scene in professional development in no way resembles the ideal of a sturdy bridge to the future — a critical link that is carefully and uniquely designed to meet particular needs. Instead, the professional development teachers experience is typically weak, limited, and fragmented, incapable of supporting them as they carry the weight of adequately preparing future citizens. Programs fall far short of helping teachers develop the depth of understanding they must have of mathematics content, as well as how best to help their students learn it.

This weakness in current professional development programs for mathematics teachers is particularly serious because, unfortunately, many teachers enter the classroom unprepared to teach challenging mathematics. The average teacher of grades K-6 takes three or fewer mathematics or mathematics education classes in college, and 20% of high school math teachers do not have a major or minor in mathematics (U.S. Department of Education, 1993-1994).

Teachers' lack of preparation becomes even more critical in light of the National Council of Teachers of Mathematics 1989 *Curriculum and Evaluation Standards*, as well as many recent state mathematics standards, which call for the teaching of more challenging mathematics. In the future, students will be expected to become mathematical thinkers and problem solvers and to learn fundamental concepts of algebra, geometry, probability, and statistics in elementary school.

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Recent US. and comparative international data show that American students should be learning more challenging mathematics. The Third International Mathematics and Science Study (TIMSS) compared the mathematics and science achievement of a half-million students from 41 countries at the fourth, eighth, and twelfth grades. In mathematics, U.S. fourth graders performed above the international average, U.S. eighth graders performed slightly below the international average, and U.S. twelfth graders performed significantly below the international average. One reason for this pattern of decline is that the content of U.S. curriculum is less demanding beginning around fourth grade and continuing through high school.

The need for more challenging mathematics content for students means that their teachers will also have to learn more challenging mathematics content and how to teach it. The purpose of this publication is to suggest new ways of designing and implementing effective professional development to reach these goals.

The need for more challenging mathematics content for students means that their teachers will also have to learn more challenging mathematics content and how to teach it.

The publication is for those who have some responsibility for designing or conducting professional development programs or initiatives. They can be teacher leaders, school or district administrators, university mathematics educators or mathematicians, curriculum developers, trainers, or consultants. They can be designing long-term, whole-district initiatives, courses for high school teachers, teacher enhancement projects drawing teachers from across a state or the nation — just about any opportunity formulated to support teacher learning. This publication may also be of interest to teachers selecting their own learning opportunities, evaluators interested in what to look for in effective programs, and funders who appreciate guidance about the kinds of programs that have the greatest likelihood of success. First and foremost, this publication is for anyone interested in "breaking set" with traditional schemes for professional development and exploring new designs for learning.

This publication can be used by any of the above audiences for identifying what works in professional development. While the strategies contained in Section II will help designers of professional development opportunities, they are included also so that educators can identify elements of programs that will lead to new ways of teacher and student learning and improved student achievement. The strategies, the additional resources, and the example programs all provide educators with a grounding in how to select programs and where to go for additional information.

Section II, Summaries of 15 Strategies for Professional Development, provides a description of each strategy including the elements necessary for design and implementation, along with issues for educators to consider. The discussion of each strategy concludes with a real-life example of the strategy in action. Readers may contact the programs for more information about these particular projects or for assistance in developing or adapting their own programs.

Section III, Successful Programs, features longer descriptions of existing programs that effectively combine several of the Strategies for Professional Development, including programs honored in the U.S. Department of Education's National Awards Program for Model Professional Development.

Section IV, Technical Assistance Providers and Additional Programs, provides brief descriptive and contact information for organizations and professional development projects that are working to offer educators training and information.

Principles of Professional Development

Knowledge from research, theory, and the "wisdom" of experienced, practicing professional developers suggests five principles of effective professional development:

1. *Professional development experiences must have students and their learning at the core — and that means **all** students.*

   Mathematics education reforms and the national, state, and local standards on which they are based, share a common commitment to high standards of achievement for all students and not just the few who are talented or privileged. This implies a different perspective on the content students should learn and the teaching strategies that should be used by their teachers. To meet this challenge, all professional development resources, including teacher time, must be focused on rigorous content and the best ways to reach all students.

2. *Excellent mathematics teachers have a very special and unique kind of knowledge that must be developed through their professional learning experiences.*

   Pedagogical content knowledge (Shulman, 1987) involves knowing how to teach specific mathematical concepts and principles to young people at different developmental levels. This kind of knowledge and skill is the unique province of teachers and distinguishes what they know from what mathematicians know. Knowledge of mathematics content, although critical, is not enough, just as knowledge of general pedagogy is not enough. The goal of developing pedagogical content knowledge must be the focus of professional development opportunities for teachers.

3. *Principles that guide the improvement of student learning should also guide professional learning for teachers and other educators.*

   Professional developers must "walk their talk" because people can only teach in ways in which they have learned. Engaging in active learning, focusing on fewer ideas more deeply, and learning collaboratively are all principles that must characterize learning for teachers if they in turn will apply these to helping their students learn.

4. *The content of professional learning must come from both inside and outside the learner and from both research and practice.*

   Professional development opportunities must honor the knowledge of the practicing teacher as well as draw on research and other sources of expertise outside schools and classrooms. Artful professional development design effectively combines theory and practice.

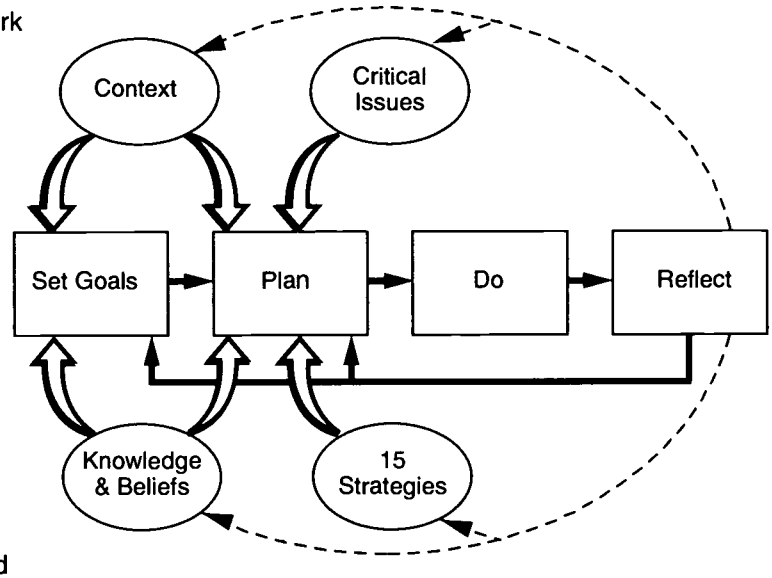
5. *Professional development must both align with and support system-based changes that promote student learning.*

   Professional development has long suffered because of its separation from other critical elements of the education system, with the result that new ideas and strategies are not implemented. Although professional development is not a panacea, it can support changes in such areas as standards, assessment, and curriculum, creating the culture and capacity for continuous improvement that is so critical for educators facing current and future challenges.

Note that the principles, design framework, and strategies for professional development described in this publication are elaborated in Designing Professional Development for Teachers of Science and Mathematics *by Susan Loucks-Horsley, Peter W. Hewson, Nancy Love, and Katherine E. Stiles, with Hubert M. Dyasi, Susan N. Friel, Judith Mumme, Cary I. Sneider, and Karen L. Worth (Thousand Oaks, CA: Corwin Press, 1998). The book is a product of the National Institute for Science Education, funded by the National Science Foundation.*

A Framework for Designing and Identifying Professional Development Programs

With these principles as a foundation, designs for effective professional development of mathematics teachers need to proceed carefully and consider a number of different elements. The figure on this page illustrates a design framework that organizes these elements in ways that suggest both how to design a new program and how to analyze the design of an existing program.



The four boxes through the middle of the framework represent a typical process of planning and action. This process reminds designers of professional development — which should include teachers, administrators, community and other resource people — of several important features of good programs:

1. There need to be goals, a set of clear and shared outcomes for the program. These goals must drive all other elements of the design.
2. There needs to be planning — careful consideration of how the pieces fit together and how to proceed over time.
3. The plan must be implemented.
4. There needs to be reflection on and evaluation of what happened that feeds back into adjustment in plans and subsequent actions, as well as in goals.

This four-step cycle is meant to repeat itself, taking place over months as a program proceeds, or in the minutes it takes to monitor and adjust an ongoing event to increase its effectiveness.

In addition to the four central steps of the cycle, the design framework considers four inputs important to the design process.

Designers of professional development need to draw upon:

1. The existing base of knowledge and beliefs about learning, teaching, the nature of mathematics, professional development, and the process of change.
2. An analysis of the context in which the teachers teach and their students learn.
3. Attention to a set of critical issues that will help them be successful or foil their attempts if neglected.
4. A repertoire of 15 strategies for professional learning that can be combined in different ways at different times to maximize different learning goals.

Illustration from: Designing Professional Development for Teachers of Science and Mathematics *by Susan Loucks-Horsley, Peter W. Hewson, Nancy Love, and Katherine E. Stiles, with Hubert M. Dyasi, Susan N. Friel, Judith Mumme, Cary I. Sneider, and Karen L. Worth (Thousand Oaks, CA: Corwin Press, 1998). The book is a product of the National Institute for Science Education, funded by the National Science Foundation. Reprinted by permission of Corwin Press.*

Knowledge & Beliefs

- *Learners and learning*
- *Teachers and teaching*
- *The nature of mathematics*
- *Professional development*
- *The change process*

Current knowledge, remarkably strong in most cases, can form a firm foundation under professional development. Research suggests that learners construct their own understandings and that certain teaching strategies — such as building on prior knowledge and active exploration of concepts — can facilitate that learning.

Effective professional development involves active study, over time, of mathematics content and pedagogy in ways that model effective learning and make direct connections with the teachers' practice. Research on change indicates the importance of attending to individual teacher needs over time, providing learning opportunities tailored to those needs, and creating a climate of collegiality and experimentation and a capacity for continuous learning and support. These knowledge bases influence design decisions for effective professional development programs.

Context

- *Students*
- *Teachers*
- *Practices*
- *Policies*
- *Resources*
- *Organizational culture*
- *Organizational structures*
- *History of professional development*
- *Parents and community*

A thorough examination of factors in the context that participants bring to the program also assists in design. The needs and nature of the students; the backgrounds, needs, and teaching responsibilities of the teachers; the resources available and degree of community support; the organization, expectations, and current demands of the schools and districts — all are important considerations in the design of professional development for mathematics teachers.

Critical Issues

- *Ensuring equity*
- *Building professional culture*
- *Developing leadership*
- *Building capacity for professional learning*
- *Scaling up resources*
- *Garnering public support*
- *Supporting standards and frameworks*
- *Evaluating professional development*
- *Finding time for professional development*

There are at least nine issues that designers of professional development must consider that carry the message: Ignore them at your peril! These may not all require attention at the onset but should be considered as the initiative or program unfolds.

Ensuring equity and supporting new standards and frameworks through professional development promote high-quality learning for all students and maximize the likelihood that current improvement efforts will reach their goals. Such issues as building capacity, developing leadership, and scaling up influence the extent to which teachers change their practice. Only when they are addressed by a professional development program will changes made by individual teachers extend beyond their classrooms to the education system.

Attention paid to garnering public support and evaluating professional development helps ensure sustained commitment to a program that works effectively. All nine of the critical issues should concern professional developers at some time in their work.

Strategies for Professional Development

Fifteen strategies for professional development are summarized in the next section of this publication. The strategies are the "toolkit" from which professional developers can design their programs or initiatives. They expand the professional development repertoire far beyond the more typical inservice workshops, courses, and institutes (although these are included as well). A well-chosen array of experiences will promote teachers' opportunities for growth in many different areas of knowledge and skill, and in a wide variety of contexts.

Those looking for a few discrete, clearly effective "models of professional development" will be disappointed that none exist. Every situation and initiative requires its own unique model. But this does not mean that each program needs to "start from scratch." As explanation of this design model indicates, there is a broad and deep base of information, research, and, indeed, wisdom that can be drawn upon to build unique and successful professional development opportunities for mathematics teachers.

References & Resources

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STRATEGIES FOR PROFESSIONAL DEVELOPMENT

STRATEGIES	PURPOSES
Immersion	
1. Immersion into Solving Mathematical Problems: Engaging in the kinds of learning that teachers are expected to practice with their students, such as inquiry-based mathematics investigations.	○ ● ●
2. Immersion into the World of Mathematics: Participating in an intensive experience in the day-to-day work of a mathematician, often in a laboratory, industry, or museum, with full engagement in research activities.	○ ●
Curriculum	
3. Curriculum Implementation: Learning, using, and refining use of a particular set of instructional materials in the classroom.	○ ○ ●
4. Curriculum Replacement Units: Implementing a unit of instruction that addresses one topic in a way that illustrates effective teaching techniques.	○ ○ ●
5. Curriculum Development and Adaptation: Creating new instructional materials and strategies or tailoring existing ones to better meet the learning needs of students.	○ ●
Examining Practice	
6. Action Research: Examining teachers' own teaching and their students' learning by engaging in a research project in the classroom.	○ ●
7. Case Discussions: Examining written narratives or videotapes of classroom events and discussing the problems and issues illustrated.	○ ○ ●
8. Examining Student Work and Thinking, and Scoring Assessments: Carefully examining students' work to understand their thinking so that appropriate instructional strategies and materials can be identified.	○ ○ ○ ●

STRATEGIES	PURPOSES
Collaborative Work	
9. Study Groups: Engaging in regular collaborative interactions around topics identified by the group, with opportunities to examine new information, reflect on classroom practice, and analyze outcome data.	○ ○ ●
10. Coaching and Mentoring: Working one-on-one with another teacher to improve teaching and learning through a variety of activities, including classroom observation and feedback, problem solving, and co-planning.	○ ○ ● ○
11. Partnerships with Mathematicians in Business, Industry, and Universities: Working collaboratively with practicing mathematicians with the focus on improving teacher content knowledge, instructional materials, and access to facilities.	○ ●
12. Professional Networks: Linking in person or through electronic means with other teachers to explore topics of interest, pursue shared goals, and address common problems.	○ ● ○ ○
Vehicles and Mechanisms	
13. Workshops, Institutes, Courses, and Seminars: Using structured opportunities outside the classroom to focus intensely on topics of interest, including mathematics content, and learn from others with more expertise.	○ ● ○
14. Technology for Professional Development: Using various kinds of technology, including computers, telecommunications, video, and CD-ROMs, to learn content and pedagogy.	○ ● ○ ○
15. Developing Professional Developers: Building the skills and deep understanding of content and pedagogy needed to create learning experiences.	○ ○ ● ○

Ⓐ Strategies that focus on **developing awareness** are usually used during the beginning phases of a change. The strategies are designed to elicit thoughtful questioning on the part of the teachers concerning new information.

Ⓑ Strategies that focus on **building knowledge** provide opportunities for teachers to deepen their understanding of mathematics content and teaching practices.

Ⓒ Strategies that help teachers **translate new knowledge into practice** engage teachers in drawing on their knowledge base to plan instruction and improve their teaching.

Ⓓ Strategies that focus on **practicing teaching** help teachers learn through the process of using a new approach with their students. As teachers practice new moves in their classrooms, they deepen their understanding.

Ⓔ Strategies that provide opportunities to **reflect** deeply on teaching and learning engage teachers in assessing the impact of the changes on their students and thinking about ways to improve. These strategies also encourage teachers to reflect on others' practice, adapting ideas for their own use.

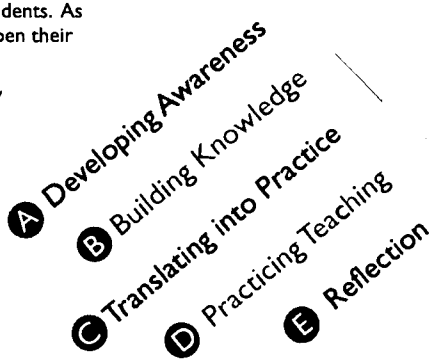

Table adapted from *Designing Professional Development for Teachers of Science and Mathematics* by Susan Loucks-Horsley, Peter W. Hewson, Nancy Love, and Katherine E. Stiles, with Hubert M. Dyasi, Susan N. Friel, Judith Mumme, Cary I. Sneider, and Karen L. Worth (Thousand Oaks, CA: Corwin Press, 1998). The book is a product of the National Institute for Science Education, funded by the National Science Foundation.

● = Primary ○ = Secondary

Summaries of 15 Strategies for Professional Development

The 15 strategies presented here have been adapted from Chapter Four of Designing Professional Development for Teachers of Science and Mathematics *by Susan Loucks-Horsley, Peter W. Hewson, Nancy Love, and Katherine E. Stiles, with Hubert M. Dyasi, Susan N. Friel, Judith Mumme, Cary I. Sneider, and Karen L. Worth (Thousand Oaks, CA: Corwin Press, 1998). The book is a product of the National Institute for Science Education, funded by the National Science Foundation.*

At the very center of professional development is the decision about which strategies or approaches to use. Of course, professional development does not occur as isolated strategies. Every program, initiative, and professional development plan uses a variety of strategies in combination with one another to form a unique design. Each strategy is one piece of the puzzle, and how strategies fit together depends on other elements of the design framework. The challenge is to assemble the combination of learning activities that best meets specific goals and context.

The following pages present descriptions of 15 professional development strategies. Each discussion includes a description of a program in which that particular strategy plays a major role. The discussions also include ways to put the strategies into action and important issues to consider when implementing the strategies.

The table on the preceding pages provides a summary of the 15 strategies, the purposes of each, and how the strategies relate to one another. References and suggested readings are listed at the end of Section II. Contact information for technical assistance providers and additional programs and services is provided in Section IV.

IMMERSION

Strategy 1: Immersion into Solving Mathematical Problems

Immersion into solving mathematical problems is the structured opportunity to experience, first-hand, mathematics content and processes. First, by becoming a learner, teachers deepen their own understanding of the mathematics content that they are teaching their students. Second, by experiencing the processes for themselves, teachers are better prepared to help students become active, engaged mathematical problem solvers.

Using this strategy is based on the assumption that teachers benefit from experiences grounded on the same principles that they are expected to implement with students. However, it is important to note that teachers must become learners by being challenged at their own level of competence. By engaging in activities appropriate for adult learners, rather than doing student activities, teachers are able to investigate mathematics content for their own learning.

The Strategy in Action

Immersion is an intensive learning experience that requires time for teachers to focus on learning mathematics in depth. They need to participate fully in the generation of compelling questions, conduct investigations that allow them to make meaning out of mathematical activities, collect and organize data, make predictions, measure and graph, and gain a deeper and broader view of the mathematics concepts they are investigating. The goal of these experiences is to engage teachers in first-hand learning of what they are expected to practice in their classrooms — guiding students through complex problem solving.

One of the most important elements in making this strategy work is the involvement of qualified instructors who have used this technique successfully with students. A second crucial component is a commitment to long-term experiences. Immersion experiences cannot be conducted in one-time-only workshops.

One outcome from in-depth immersion in the problem solving process is a change in teachers' conceptions of the nature of mathematics learning and teaching. As teachers begin to see mathematics teaching as less a matter of knowledge transfer and more an activity in which a problem is explored and the math content embedded in it is investigated in depth, they see their own role as teacher changing from a direct conveyor of knowledge to a guide helping students develop their own meaning from experience.

Issues to Consider

Even with extensive coursework in their preservice programs, many teachers come to the teaching of mathematics without having had opportunities to engage in complex problem solving themselves. Although the benefits of immersion may be well recognized, teachers with limited time and programs with limited resources may not be able to afford in-depth experiences, opting for shorter term activities using student learning materials.

Where immersion in solving mathematical problems best fits into a learning sequence is another issue. Some use the strategy to initiate teachers into a new view of mathematics. Others may choose it as a more in-depth enrichment, once teachers learn to use and are comfortable with a set of materials for their students.

Immersion into Solving Mathematical Problems is a key ingredient in SummerMath for Teachers, located at Mount Holyoke College. This intensive summer program is based on the belief that teachers must become mathematics learners if they are going to teach for understanding; that this best happens when they are challenged at their own level of mathematics competence; and that they must be given learning experiences based on the same pedagogical principles as the ones they are expected to implement with children (Schifter and Fosnot, 1993). Participating teachers have the opportunity to learn mathematics and to discuss the experience as well as the structure of the lesson and the roles of the teacher and students. But, as Schifter and Fosnot (1993, p. 26) point out: "perhaps more important for [the teachers] than their investigation of any specific content area is the process of active self-reflection. By analyzing together their experience of the just-completed mathematics activity, teachers begin to construct an understanding of how knowledge develops and the circumstances that stimulate or inhibit it." See Section III (page 44) for more information about how SummerMath for Teachers has had an impact on the professional development activities in the Northampton, Massachusetts, School District.

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Strategy 2: Immersion into the World of Mathematics

The majority of teachers have never had an opportunity to actually "do" mathematics in a real-world setting. By becoming a mathematician in a research environment, teachers deepen their knowledge of mathematics and, as part of a research team, develop skills in sharing and critiquing mathematical information with other professionals.

In quality research programs for teachers, a product of the experience is a detailed plan for extending experiences into the classroom. Many programs offer teaching materials, electronic connections, and other networking facilities for continued support. These experiences provide teachers with the knowledge to "teach beyond the textbook" and to simulate in their classrooms the processes mathematicians use to solve problems.

For their own professional growth, teachers need to have authentic experiences outside of the classroom. Most find that becoming an active member of a research team not only improves their content knowledge but also prepares them for leadership roles in their profession.

The Strategy in Action

Immersion experiences with a mathematics research group have several important components. The experience needs to be intensive, allowing the teachers to learn the content, process, culture, and ethos of mathematics problem solving. Teachers often select their own area of research and are paired with a mentor mathematician, usually during an intensive summer program.

All involved in the immersion experience need to have open, frequent communication about the assignments and experiences of the teachers. Teachers attend seminars and read materials on the mathematics topics related to their research. As part of their immersion into the professional community, teachers participate in activities outside of their research that enhance their experiences and contribute to their knowledge base.

Most immersion programs encourage all members of research teams to both individually and jointly present their findings and experiences at meetings and in journal articles. Programs also encourage research team members to maintain communication and view their mentors as resources, in some cases inviting them to visit their classrooms throughout the school year. Other programs offer reunions at regional or national conferences, newsletters, and electronic networks.

Planning ways for teachers to bring the experience back to their classrooms is an important component of the program. An expert in mathematics education must be intimately involved in the experience so teachers have guidance in creating action plans to transfer what they have learned to their students. Once they return to their classrooms, teachers need support from their school administrators to change instructional practice. This may include additional resources and materials, as well as permission to deviate from the standard curriculum. As always, the goal of quality professional development is better education as demonstrated by improved student achievement.

Issues to Consider

While an immersion experience can be extremely rewarding for teachers, and result in changes in classroom practice, there are several pitfalls. First, mathematicians sometimes prefer high school teachers who already have degrees in mathematics. This somewhat limits the pool of teachers who can benefit from this kind of experience.

Second, there is the question of the degree to which teachers are able to translate their internship experience into the classroom. Some have been frustrated by a lack of materials and by colleagues and administrators who were unwilling to change. One solution is the development of partnership agreements with school districts to implement changes based on the teachers' research experience. Unfortunately, restricting participation to teachers in districts that develop

such partnerships also limits who is able to benefit.

Another issue concerns the relationship between mathematicians and teachers in the research environment. At best it is collegial, but there is always the danger that teachers will be given repetitive tasks with little explanation, or that they will attend lectures with advanced mathematics content and might then try to pass on the knowledge in a similar manner to their students. This problem can be addressed through careful orientation of mentors and guidance in selecting teacher research assignments.

Finally, since this is a "one teacher at a time" professional development experience, it can be expensive, well over $10,000 per teacher. Studies of the cost-effectiveness are ongoing, as are explorations of ways to reduce the cost and/or reach more teachers. Some corporations and businesses are working with universities and research facilities to create sponsored internships for teachers.

[redacted]

Immersion into the World of Mathematics is exemplified by Project GEMMA (Growth in Education through a Mathematical Mentorship Alliance) in Dayton, Ohio. The program brought together teachers and administrators from school districts, mathematics and science educators from universities, and professionals from several industries and businesses, including Wright Patterson Air Force Base, which incorporated GEMMA into Project Wright Connection. The purpose of the program was to improve the mathematics education of all students in the county's public schools. Teachers discovered connections between mathematics and science, engineering, and other disciplines used in the workplace. During the internship, each teacher was assigned to a mentor to guide him or her through the completion of a project at the industry or business. The teacher was expected to make a contribution, not just be a spectator, while observing how people in industry operate, what skills they need, and how they use mathematics in their daily work.

During the internship, teachers attended seminars where they discussed their experiences in the workplace, the applications of mathematics they learned, and how they planned to share this with their students. As a result of their experiences, they developed a booklet of applications problems that they piloted and revised during the school year. In follow-up reunions, teachers reflected on what they experienced during the internship and what they transferred to the classroom (Farrell, 1994).

(continued)

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CURRICULUM

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Strategy 3: Curriculum Implementation

Curriculum is the way content is designed and delivered. It includes the structure, organization, balance, and presentation of the content in the classroom (National Research Council, 1996). As defined here, curriculum is a set of materials that includes both content and instructional guidelines. The "set" of materials may be from one publisher or developer or may have been selected from a variety of materials organized by the school or district.

Putting new curricula into practice in the classroom can serve as a powerful professional development opportunity for teachers. Through using a particular curriculum with their students, reporting on what happens, and reflecting with others on different ideas and activities, teachers learn about their own teaching and their students' learning (Ball, 1996).

Note that this strategy focuses teachers on learning about the new curriculum and how to use it — not on researching, designing, testing, and/or revising curriculum, as will be described in Strategy 5, Curriculum Development and Adaptation.

The Strategy in Action

This strategy relies on teachers having access to high quality curriculum materials, developed by people with expertise in content and pedagogy, as well as sufficient resources and time to design, test, and refine the materials for use in classrooms with diverse students.

Teachers and professional developers need to work together to decide how the curriculum will be used with students and the milestones that will be met at different points in the implementation process. Over time, teachers need to be given different kinds of support, tailored to their changing needs. Teachers share insights with one another as they implement the new curriculum. They also coach one another, conducting classroom visits to support the learning of both teachers and students.

It is crucial that school officials acknowledge that implementing curriculum takes time, resources, and a commitment to reform. In addition, the district must institutionalize the change by ensuring the continued use of the curriculum after the initial phases. Plans must be established for ongoing professional development for all teachers and support of new teachers or teachers who change grade levels.

Finally, mechanisms for evaluation must be developed. While data may include information about student learning outcomes, evaluation of the implementation strategies are essential, especially in the early stages. Teachers and professional developers can then use this information to adjust what they are doing.

Issues to Consider

While virtually all schools implement new curricula at some time, often they do not organize the implementation in ways that promote effective professional development. It is not uncommon for curriculum to be changed and teachers to have opportunities for professional development with no connection between the two.

Using curriculum implementation as a vehicle for professional development combines two major pieces of the system — curriculum and teaching — so changes will reinforce both. A second benefit is the efficiency of teachers learning directly what they need to teach. This contrasts with the situation in which teachers learn content and teaching strategies separately, but they have no ready-made vehicle to put these together in their classrooms. Finally, this strategy is also beneficial because it provides a focus for teacher reflection.

On the other hand, professional developers must recognize the tension between a mandate to implement a new curriculum and teacher creativity. It is important for teachers to know how much adaptation they can do and still be viewed as implementing the curriculum effectively. The nature of acceptable adaptations requires early and ongoing negotiation.

One additional danger with this approach is that professional development support will stop once (or before) the curriculum is fully in place. This disregards the need for continuous deepening of teacher knowledge and skills. The mechanisms for teacher reflection, sharing, assessment, and adjustment should become part of the overall school routine.

Curriculum Implementation is an important component of the QUASAR (Quantitative Understanding: Amplifying Student Achievement and Reasoning) Project. Since 1989, QUASAR has fostered the development and implementation of enhanced mathematics instructional programs for students attending middle schools in economically disadvantaged neighborhoods across the country. At each school site, mathematics teachers and school administrators collaborate with "resource partners" to implement an innovative mathematics instructional program for all students at the school (Stein, Silver, & Smith, in press).

One QUASAR school, Portsmouth Middle School in Portland, Oregon, designed a program to implement Visual Mathematics (VM), an innovative curriculum that embodies many of the recommendations of the NCTM Standards (1989). To prepare for implementing the VM curriculum, all mathematics teachers received 60 hours of

(continued)

instruction to familiarize them with the mathematical content and pedagogy of the curriculum, as well as with issues related to current mathematics reform. Following the workshops, teachers also participated in monthly, full-day staff meetings and continued to receive daily support, both from their resource partners and, as they gained confidence, from each other. For more information on how this program coordinated the use of a number of other Professional Development Strategies, see Section III of this publication.

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Strategy 4: Curriculum Replacement Units

Curriculum replacement units are not designed to supplement the existing curriculum, rather they are coherent chunks that provide an alternative experience with traditional topics or introduce new topics that are not currently part of the curriculum. They illustrate the way state and national standards documents say mathematics should be taught. This strategy offers a window through which teachers can glimpse new teaching in action; with this strategy, teachers can engage in different teaching practices without overhauling the entire program.

Replacement units are used for professional development in two ways. In the first case, it is not intended that the units be "adopted" or used over the long-term. Rather, the units are used to stimulate teacher reflection and understanding of how content should be taught. The second use of replacement units shares these goals, but the intention is to replace the entire curriculum, one or two units at a time.

A key in this strategy is use of high quality replacement units with a strong emphasis on mathematics content. As Burns (1994, p. 2) notes, quality replacement units in mathematics "integrate important mathematical topics and help students make sense of mathematics; appeal to students because the activities stimulate their thinking and imaginations and make mathematics interesting; appeal to teachers because they have been tested in classrooms and reflect input from teachers with experience teaching them; offer clear teaching plans, yet are broad enough to accommodate teachers veering from the plans to follow leads from students or add their own ideas; provide direction for assessing student understanding; allow for a span of abilities and interests; encourage students to communicate about mathematics, both orally and in writing; and provide opportunities for students to work individually and cooperatively."

Criteria for selection of replacement units include:

- Units must teach important mathematics concepts in ways recommended by the state and national standards;
- Units must stand alone and require only equipment and materials readily available to the teacher;
- Units must be grade-level appropriate and accessible to a wide range of students.

The best replacement units are carefully designed with sufficient investment of money, time, and expertise. Given teachers' limited time and resources, curriculum units created by expert curriculum developers are usually better learning tools than units teachers develop themselves. As teachers learn how to implement replacement units, they need to be grounded in the theoretical and practical aspects of the new teaching approach. This may involve trying out the activities as learners, attending workshops where they can learn from teachers experienced in the units, and practicing the new techniques.

When teachers try out the units in their own classrooms, they deepen their owner-

ship of the new teaching strategies. Then they need a chance to evaluate the impact these practices have on students. Opportunities for dialog deepen understanding and can motivate teachers to broaden their application of the new approach to other parts of their curriculum.

If teachers are expected to try out new teaching practices in their classrooms, they need assurance that experimentation is supported by administration and parents. Teachers also cannot be expected to add new curriculum units to their already over-loaded existing curriculum. Something has to be abandoned so that teachers can successfully implement replacement units.

Issues to Consider

Use of curriculum replacement units is a cost effective approach to providing professional development. However, no strategy is without its disadvantages. One disadvantage of replacement units is that teachers may place too much emphasis on the units and not enough on the learning experiences — both theirs and their students' — that come from using them. They often begin to teach the units without examining how to make the new content an integral part of their curriculum.

Another disadvantage of replacement units arises out of teachers' enthusiasm for them. In some cases, teachers attempt to combine a series of replacement units to create a whole curriculum. This well-intentioned effort often results in a curriculum that lacks scope and sequence, conceptual flow, and coherence. At other times, the replacement units become simply supplemental activities and do not have the intended outcome of improving student achievement.

Teachers who do begin to change their teaching practices through using replacement units and move toward integrating them into the rest of their curriculum, often experience a major stumbling block: finding quality instructional materials that incorporate effective teaching practices. In the absence of new materials, individual teachers seek to modify and adapt the existing curriculum. This desire for new instructional materials brings to the forefront other professional development challenges: how to help teachers ensure that appropriate skills and concepts are still presented to the students and how to evaluate commercially produced materials to select those that are appropriate for their students and also incorporate the new content and teaching practices.

The California Mathematics Renaissance Network has used Curriculum Replacement Units to improve the teaching of mathematics in middle schools throughout the state. During the 1994-95 school year, more than 1,500 teachers from some 400 middle schools engaged in the program's year-round professional development opportunities. The focus is on discussing mathematics reform, experiencing hands-on mathematics, learning how to teach new state-of-the-art curriculum replacement units, and exploring the conditions that create opportunities for learning. Inherent in the professional development strategy of using replacement units is Mathematics Renaissance leadership's belief that: "teachers must experience reform in their own classrooms and have opportunities to grapple with the difficulties that arise. Focusing the talk on [replacement units] has been particularly helpful to the process. Teachers have attended unit workshops and then taught the units while cluster leaders observed them. They've brought questions, concerns, and successes to their cluster meetings and shared their students' work with their colleagues. Their experience with alternative curricula has prompted examination, inquiry, and collaboration. This approach has allowed teachers to be exposed to big mathematical ideas in coherent, practical-sized chunks — pieces small enough to seem manageable to even the most reticent" (Acquarelli & Mumme, 1996, p. 482).

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Strategy 5: Curriculum Development and Adaptation

In the past, the goal of curriculum development has been simply to create a new curriculum that will then be implemented within a mathematics department. More and more, curriculum development and adaptation are being viewed as effective strategies for professional development.

In this strategy, the term "curriculum" refers to content-specific materials used in classrooms as well as the articulated content matrix that identifies the concepts to be addressed at each grade level. Curriculum adaptation refers to the process of taking existing curriculum materials or content matrices and modifying them to more fully meet the needs of everyone involved.

This strategy is based on the assumption that those closest to the level of implementation are well suited to develop curriculum. Teachers come to the table with a wealth of knowledge that prepares them to develop or adapt mathematics curricula. Through the curriculum development process, teachers increase their content and pedagogical knowledge and reflect on their teaching.

Development or adaptation of parts of a curriculum also contribute to teacher learning because these activities cannot be accomplished unless teachers think deeply about how the specific section fits into the broader goals of the entire curriculum. They need to understand state and local frameworks, national standards, the appropriateness of content and concepts presented at each grade level, and the sequence of other topics offered in each grade level.

The Strategy in Action

For this strategy to be most effective it must provide numerous opportunities for teachers to learn from others with expertise outside the classroom. As teachers work together on a mathematics curriculum, they engage in research, collaborate with experts in relevant fields, and develop networks with peers and experts. In many cases, mathematicians are active participants with teachers in the process of developing or adapting curriculum, adding to teachers' opportunities to learn.

Most curriculum development or adaptation efforts begin with specific guidelines, ideally designed by all involved. Teachers and administrators set clear goals, define products, and develop an effective timeline. Everyone also must understand the district standards or curriculum framework. The next step is evaluating current practices, assessing what is needed, determining implementation procedures, and identifying a process for evaluating the final curriculum.

Administrators must encourage the curriculum development process by providing time and incentives for teachers to participate, ensuring access to resources and experts, and supporting long-term improvement of the curriculum that is ultimately developed. It is also essential that teachers are given the authority to implement the curriculum they develop or adapt.

Curriculum development or adaptation is most successful as professional development for teachers when it is voluntary. Developing and adapting curricula are complex and intensive tasks in which teachers need to choose to participate.

Issues to Consider

Before choosing this strategy, professionals developers must realize that teachers usually do not have the time to devote to the intensive process of developing curriculum — researching, writing, piloting, revising, field testing, and revising again. Most frequently, teachers are available only during the summer months for such an intensive effort. While adapting an existing curriculum is a more reasonable task for a summer, this process is better conducted over even a longer period. Without time to reflect on the work, the professional development benefits of writing and adapting curricula are limited and the effort becomes one of simply creating a product.

A separate issue is expertise. Many argue that teachers are not the most qualified to

develop curriculum. Although teachers often know what teaching and learning strategies are effective in a classroom, how children best learn content, and what content is age-appropriate at certain grade levels, some experts believe that they do not have the "big picture" perspective on the overall curriculum. Nor do they have specialized expertise of instructional design and curriculum planning, plus the deep mathematics content knowledge needed to craft a full sequence of learning experiences that build across grade levels. It is certainly possible for teams of teachers from across grade levels to collectively possess sufficient knowledge that, when given time and access to resources, they can be effective in designing a curriculum. The issue is not whether this is possible, but whether starting curriculum development from scratch is the best use of limited resources. This is certainly where curriculum adaptation has advantages over development. And, in either case, professional learning occurs during the process.

Curriculum Development and Adaptation is used as a professional development strategy in the Systemic Initiative for Montana Mathematics and Science (SIMMS) Project. The initiative has nine major objectives, including the redesign of the grade 9-12 mathematics curriculum using an integrated mathematics program that emphasizes the relationship among topics within mathematics, as well as between mathematics and other disciplines. The curriculum is written, revised, and reviewed by high school teachers of mathematics and science and is designed as a complete curriculum to replace existing courses. The materials are divided into 16 modules, each addressing the integration of mathematics topics.

A significant component of the curriculum development activities in the SIMMS Project is professional development. Teachers attend intensive, week-long summer institutes. In developing curriculum, participants select from among three strands: mathematics as a lab discipline, assessment, and the T3 model (Teachers Teaching with Technology).

(continued)

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To order the curriculum:
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EXAMINING PRACTICE

Strategy 6: Action Research

First introduced by Kurt Lewin in the 1940s, action research has evolved into an ongoing process of systematic study in which teachers examine their own teaching and students' learning through descriptive reporting, purposeful conversation, collegial sharing, and reflection for the purpose of improving classroom practice (Miller & Pine, 1990).

The emphasis of action research is on practice-based professional inquiry. Its main tenet is that practical problem solving in the classroom is adequate for generating knowledge and that the natural language of teachers is suitable for reporting action research findings. (Duckworth, 1986).

Holly (1991) notes that "... action research as a major form of professional development, is now seen as central to the restructuring of schools" (p. 133). The

strength of action research as a professional development strategy is that teachers either define the research questions or contribute to their definition in a meaningful way. Therefore, the teachers are committed to promoting changes indicated by the findings.

The form of the action research can vary. Sometimes teachers work together in inquiry teams or with other researchers, often from universities. Other times, individual teachers pursue their own research studies, with opportunities to discuss findings with fellow teachers or researchers. Still other variations have teachers examine relevant research, which is then used as a basis for collecting and analyzing data from their own classrooms (Loucks-Horsley, Harding, Arbuckle, Murray, Dubea, & Williams, 1987).

Action research assumes that knowledge about teaching and learning should be determined in part by what teachers and students actually do (Miller & Pine, 1990). Direct teacher involvement with research will increase the likelihood that they will use research results. It gives teachers the power to make decisions and puts them in the position of accepting responsibility for their own professional growth (Miller & Pine, 1990; Sparks & Simmons, 1989; Wood, 1988).

The Strategy in Action

This strategy requires that teachers use an action research cycle of planning, acting, observing, and reflecting. Teachers identify a subject of research and develop a plan of action, often in collaboration with others. Data are collected by observation, anecdotal records, checklists, videotaping, logging, collecting children's work, interviewing, and surveying, among other techniques. Data are analyzed and used to inform further planning and subsequent action.

As in all research, effective action research projects build on available knowledge, rather than recreating it. Individuals, such as university researchers, offer expertise on the knowledge base and on research methodology to help teachers to ensure the quality of their research (Holly, 1991). In the process of conducting an action research project, teachers gain knowledge and skill in research methods and applications (Lieberman, 1986; Miller & Pine, 1990; Oja & Smulyan, 1989).

Sharing the results of action research can make a significant contribution to professional development. Opportunities to write about a project, to present findings to various audiences, to participate in discussions of the implications, and to develop materials that other teachers can use are just some of the ways that teachers can increase their skills and knowledge beyond what they learn from the action research itself (Loucks-Horsley et al., 1987). Assisting teachers to identify the best vehicles for sharing is an appropriate role for the professional developer.

Issues to Consider

One of the most serious issues facing the action researcher is the significant quantities of time needed to observe how different strategies work with different students and under different circumstances. Teachers deserve to be recognized for the time spent in action research projects and have it count toward district or state professional development or recertification credit. Teachers and administrators can examine the school schedule to find common time for teachers to work together on a research project, during the day, if possible.

Another issue is the lack of recognition for professional development that is not in the form of institutes or workshops. Both administrators and participating teachers can show support by publicly acknowledging the value of action research. Teachers can help convey the importance of their projects by providing regular updates to all staff on their progress.

Finally, not all teachers are ready to serve as action research participants. Teachers differ widely in their priorities and interests and these change over time. Teachers who are struggling to get new practices working may not be ready to collect data, then step back and reflect on them.

Action Research became an important professional development strategy for Barbara Shelley, a teacher from the Westhill School District, New York. She was implementing the use of computers in her mathematics classes and wanted to look at how student interactions within small groups affected student learning. Shelley notes, "Action research lends itself to classroom use through professionally inquisitive teachers. When this happens, the classroom becomes a learning environment for the teacher as well as the student. It involves doing what comes naturally to teachers, questioning classroom practices."

Her action research project led to a large National Science Foundation Small Grant for Exploratory Research (SGER) which, in turn, led to a $650.000 NSF Teacher Enhancement Grant: Mathematics Teacher/Researcher Collaboration for Collaboration in the Classroom (MTRC3), co-directed by Shelley along with Nancy Zarach, an urban high school teacher, and Patricia Tinto, a Syracuse University researcher. To date, the project has brought action research to 36 secondary mathematics teachers in 15 rural, suburban, and urban districts in Central New York.

For more information about these and other action research projects, visit the TeachNet Web site:
http://www.teachnet.org/docs/shelley2.htm

Strategy 7: Case Discussions

Cases are narratives in print or on videotape that offer a picture of a teaching or learning event. They are not simply stories about teaching or learning but are, as Shulman (1992) states, focused on a teaching dilemma, student engagement in mathematics investigations, images of student thought processes, or teaching strategies in action. The classroom videotapes in the Resource Kit developed to share the results of the Third International Mathematics and Science Study (TIMSS) are powerful examples of videos that can be used to evoke deep reflection on instructional practice (U.S. Department of Education, 1997).

The process of reflecting on students' thinking and learning through case discussions often results in teachers trying out the ideas or activities contained in the cases in their own classrooms (Barnett, 1991; Davenport & Sassi, 1995; Schifter, 1994). The vivid images of students in the cases prompt teachers to wonder about the thinking of their own students. Case discussions can also be a powerful tool for helping teachers examine their own teaching practices. In these instances, cases typically convey a contextual dilemma, as well as the internal struggles of the case teacher (Schifter, 1996).

Additionally, when teachers confront mathematics issues through the lens of students' perspectives, they often deepen their own content knowledge (Schifter & Bastable, 1995). As teachers reflect on students' approaches, they begin to think through the mathematics again for themselves, often seeing new aspects of familiar content and expanding their own understanding (Russell et al., 1995).

Cases can present complete stories that describe how the case teacher addressed the dilemma (Schifter, 1996). Others end instead with a series of open-ended questions. Some convey the complexity of teaching (Merseth, 1991), while others focus on discrete instances of teaching. Finally, some cases are grouped into clusters based on similar themes. Examining clusters of cases requires teachers to grapple with the theme in different contexts (Barnett & Friedman, in press).

Case discussions provide a more focused picture of a specific aspect of teaching or learning than one could observe in real-time in the classroom. Often, observers in a classroom focus on management and miss opportunities to address specific teaching or learning episodes. By using cases, participants focus on the same situation and have the immediate opportunity to reflect specifically on those experiences during the case discussion.

Whatever the focus of a case, all case discussions share common goals: to deepen teachers' fundamental understanding about teaching and learning; to provide opportunities for teachers to become involved in critical discussions of actual teaching situations; and to encourage teachers to become problem-solvers who

pose questions and examine alternative solutions (Barnett & Sather, 1992; Shulman & Kepner, 1994).

The Strategy in Action

Case discussions require a knowledgeable facilitator who prompts reflection by case discussants. Facilitators must have a deep understanding of the mathematics content illustrated in the cases. In addition, they must have the skill to turn discussions that are intellectually stimulating, and challenging — at times even confrontational — into supportive and ultimately useful dialogs. Handbooks and training opportunities are available to help facilitators develop these skills (see the Reference list at the end of Section II as well as Section IV: Technical Assistance).

It is also essential that case discussion groups create an atmosphere of learning and trust. Since participants rely on discussion to tease out insights, they and the facilitator need fairly sophisticated communication skills to challenge assumptions, understand different perspectives, and dig deeply into underlying structures that support mathematics teaching and learning. If participants do not have experience with this type of dialog, they need coaching by the facilitator before beginning their case discussions.

Another key component is the use of relevant and recognizable cases. Although some cases depict situations that reflect the "ideal image" of what teaching and learning can look like, teachers need, at least initially, to be able to identify aspects of their own teaching within a case. Once teachers feel a sense of connection with a case, they can delve deeper into how the situation is related to their own teaching approaches. Some cases will present notions that conflict with the beliefs of the teachers. "Wrestling with the resulting disequilibrium" leads to changes in teachers' thinking (Barnett & Sather, 1992).

Not only is participating in case discussions a powerful professional development strategy, but the process of writing cases also enhances teachers' development. Usually, teacher-writers follow a structured case development process that progresses from identifying an issue of concern to collaborative work with an editor who helps turn the narrative into a case that has benefits for a larger audience. Most teachers who have written cases report that the writing process has a strong impact on their professional lives (Shulman & Kepner, 1994).

Issues to Consider

One question currently being asked is whether case discussions must be conducted face-to-face, or whether they can be done electronically. Bank Street College conducts successful electronic case discussions as part of their telecomputing courses. (This program is discussed in detail in Strategy 14, Technology for Professional Learning.) On the other hand, there is good reason to argue that, because they often challenge teachers' deeply-held beliefs, case discussions are best conducted in person. The face-to-face dimension can be critical in establishing rapport and communicating disagreements in constructive ways. Preserving these benefits via electronic means presents a considerable challenge.

Another issue is whether being part of a discussion group is essential for this strategy. Although teachers can certainly learn many things from reading cases on their own, many of the real benefits derive from the group process itself. It is difficult, if not impossible, to throw oneself into the kind of disequilibrium Barnett and Friedman (in press) have shown to be the essential first step to changing beliefs and practices. In addition, the diverse contributions of the group are what determine the unique nature of each case discussion.

The question of whether unfacilitated discussions are as effective as those that are facilitated is another critical issue. The role of the facilitator in many case approaches is more than that of a guide. Particularly in those instances where the approach includes published case facilitation guides or notes, the facilitator can be responsible for encouraging the group to address certain issues raised in the guides. Without a facilitator, some of these issues might be left unexamined.

Finally, people who use case discussions, and especially those who write their own cases, need to be concerned about the

confidentiality and ethics involved in this strategy. Case discussions need to be treated like cases in other professions, such as health, law, and social services. Participants must ensure that materials such as videotape, print descriptions, and pictures are used with consent and that all materials viewed are kept confidential by the group (Kleinfeld, undated).

Cases and their discussion are the focus of the Mathematics Case Methods Project at WestEd in San Francisco. The project aims to build the capacity of teachers to make informed strategic decisions that anticipate student thinking through the development and analysis of mathematics cases. The cases are accounts of classroom experiences written by teachers; in each case, the teacher is perplexed by students' responses or by the results of an assessment task (Barnett & Friedman, in press). Included in the cases are descriptions or samples of student work or dialogues. After reading a case, teachers discuss issues raised in a session guided by a facilitator, a teacher with case discussion experience who has been formally prepared to facilitate the sessions. Barnett and Friedman identify many outcomes from teachers' participation in case discussions. Cases provide a powerful stimulus for changes in teachers' beliefs about how mathematics should be taught; they lead to improvement in teachers' mathematical content knowledge; they increase the complexity of teachers' pedagogical content knowledge; and they lead to changes in teachers' classroom teaching practices.

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Strategy 8: Examining Student Work and Thinking, and Scoring Assessments

"Real student work gives teachers a starting point for conversations that get to the essence of what happens in classrooms. Samples of student work are concrete demonstrations of what is known and what is not known" (Evans, 1993, p. 72). Using the professional development strategy of examining student work and thinking, and scoring assessments is based on several assumptions about teaching, learning, and professional development.

The closer a professional development opportunity brings teachers to student learning, the better. This philosophy is in contrast with professional development that focuses on teaching practices. Examining student work focuses teachers' attention on the consequences of their teaching and demonstrates discrepancies between what teachers believed they were teaching and what students appear to have learned (Driscoll & Bryant, in press).

It stands to reason that more learning occurs when teachers confront real problems. Such is the case with student work and assessments, which teachers use to judge the quality of learning and, in some cases, teaching. As Ball and Cohen (1995) indicate, there is value in using a real task of practice as a context for learning.

There are many who see this strategy as the most powerful way to help teachers improve their practice. Clearly, it is totally "authentic" in that teachers work with products of student thinking and study closely the very thing they are responsible for improving. As professional development becomes more results oriented, there is no better way to focus on learning.

The Strategy in Action

The availability of student work may make this appear to be an easily applied strategy for professional development. However, professional developers need to keep in mind that student work samples should be varied in their nature and quality. Rather than consisting of short answers, the samples must include students' explanations of their thinking (e.g., why they answered the way they did).

The focus of teachers' discussion of student work may vary. Sometimes disappointing student performance on a standardized test will give teachers a compelling reason to examine the actual

examination questions and their students' answers. At other times, teachers might discuss examples of student classroom work that puzzle them. In some situations, teachers may begin with a rubric supplied by others to apply to a set of student work or may take the opportunity to develop their own rubric through examining student answers. Or, the focus for a discussion may be a videotape of children's explanations of their understanding of a problem or situation.

Although individual teachers can certainly examine student work on their own, there is power in discussing the work as a team. As elementary teacher Christine Evans (1993) points out, working together greatly enhances the process. Across her teaching group, ideas differed about the mathematics, the tasks, and particular students. Together they began to develop shared standards that could guide their collective efforts. Creating a supportive environment allows teachers to work with each other and examine their own values notes Rebecca Corwin (1997, p. 187), "...doing mathematics together in a responsive group creates a safe professional community in which to explore issues and raise questions about both mathematics and pedagogy."

The guidance of an expert with deep mathematics content knowledge is especially important in this strategy. Often, understanding what students are thinking by analyzing their written work requires substantial knowledge of the mathematics topic. Similiarly, if students' responses on standardized tests or the effectiveness of the tests themselves are being examined, it is helpful to have the guidance of someone with experience in assessment.

Issues to Consider

It is useful to think about how this strategy can be combined with others to optimize professional learning. For example, teachers implementing a new curriculum can bring examples of student work to follow-up sessions. Case discussions can (and often do) relate to student work, with teachers analyzing in some depth what students did and what teachers can learn from that. Action research and peer coaching can pay special attention to observations of students talking to each other, or working on problems or investigations and questioning them about what they are doing and why. Video cases of teaching, including CD-ROMs, can be accompanied by student work, so viewers can get a deeper understanding of what students are learning.

The most important aspect of this strategy is that teachers develop for themselves the ability to understand the content students are struggling with, and ways that they, the teachers, can help. Pedagogical content knowledge, that special province of excellent teachers, is absolutely necessary for teachers to maximize their learning as they analyze student work.

An example of how teachers can use the examination of student work as a professional development strategy is seen in Project IMPACT, a collaboration between the University of Maryland at College Park and Montgomery County Public Schools, Maryland. The Project focuses on helping teachers identify and build on students' existing knowledge through close examination of student work (Campbell & Robles, 1997). During summer programs, teachers explore how a classroom activity might facilitate a child's re-examination of an important mathematical idea. Teachers also write questions that they could ask of students to determine what mathematical ideas the children formed as they completed the activity. To encourage teachers to transfer what they themselves have learned to their students, they are challenged to define a task that would address the same mathematical topic at a level appropriate for their students. For another example of this strategy, see the profile of the Award-Winning Professional Development Program at Woodrow Wilson Elementary School, in Manhattan, Kansas, described in Section III.

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Strategy 9: Study Groups

Topics addressed in study groups vary from mathematics content knowledge to current issues in mathematics education to whole school reform. Groups may be composed of small numbers of teachers interested in pursuing a topic together or entire school faculty addressing broad reform issues. Regardless of the topic, study groups provide a forum where teachers can address issues that impact student achievement.

Use of this strategy is based on the assumption that teachers have the knowledge, skills, and desire to design study groups that best meet their own needs and those of their students. Addressing issues related to their own classrooms allows teachers to develop new practices directly related to their local contexts. Unlike professional development experiences designed by others, study groups provide a forum where teachers can address issues that embody central values relevant to their own students' learning (Little, 1993).

Teachers' participation in study groups helps create a community of learners that promotes continuous improvement as a way of life in the school. Moving out of classroom isolation to share ideas with peers in a supportive group fosters a sense of professionalism among teachers. Study groups also provide an opportunity for teachers to develop a common language to reflect on classroom instruction and the needs of their students.

The Strategy in Action

One of the primary elements of this strategy is that groups are organized around a specific topic of importance to the participating teachers. For example, grade-level teachers might form a study group to learn more about assessing their students' understanding of mathematics concepts. Over a period of time they might meet to discuss research they have read, critique different types of assessments, or invite district personnel to join the group to discuss assessment requirements and how they affect classroom practice.

Makibbin and Sprague (1991) suggest four models for structuring study groups.
1. The implementation model is designed to support teachers' use of techniques recently learned in workshops or other short-term sessions.
2. The institutionalization model is used once teachers have already implemented new practices in the classroom and want to continue refining these practices.
3. Research-sharing groups are organized around discussions of recent research and how it relates to classroom practice.
4. Investigation study groups are a way for teachers to identify a topic they would like to research.

Like most other strategies for professional development, participating in a study group requires time. Some suggest a minimum of at least once a week over a period of several months (LaBonte, Leighty, Mills, & True, 1995; Murphy, 1992, 1995). It is critical that groups keep a regular schedule of consistent contact.

Success of study groups requires direct support from school administrators, not only for the time for the group to meet, but also support for the endeavor itself. Administrators send a clear message of the importance of professional development for teachers if time is set aside during the school day for study groups to convene. Administrators can also offer support by providing access to additional resources, such as new technology or outside experts.

Most groups use a variety of activities, including reading and discussing research, attending workshops, or inviting experts to work with the group. Some groups implement new practices in their classrooms and use the study group time to analyze the experience, both for themselves and their students.

As with other strategies organized around cooperative work, group interaction skills are important. Successful groups have members who are committed to accomplishing a common goal; work to create an environment of trust; believe that each member brings something unique to the

group; value risk-taking and creativity; are able to plan and implement change; share leadership of group processes; and are comfortable with consensus decision-making procedures.

Issues to Consider

Teachers forming study groups need to identify a topic that is "complex and substantive enough to hold the group together while individuals are developing the skills of working together as a cohesive group and developing trust and rapport" (Murphy, 1995, p. 41). Teachers just embarking on collaboration with their peers will need time to become comfortable with the process. If the initial topic is too narrow, the group may find itself moving from topic to topic without really reflecting on what they are learning.

Because this strategy necessarily involves teachers in reflection outside of the classroom, it is difficult to sustain study groups. However, once study groups "take hold" in a school, teachers enthusiastically support their continuation. Administrators come to recognize their benefit as a way to build ownership and commitment by a broader school community.

Study Groups became an important professional development strategy for 10 elementary teachers in Cleveland. Teachers interested in enriching their classroom practice were asked to join the group, which they called Journeys. Members expressed a sincere commitment to the goals of the study group and clearly displayed a desire to explore their teaching more deeply.

The Journeys group convened regularly for four years. Initial sessions were more social than intellectual, helping members to develop an environment of mutual trust and understanding. Over the four years, their goals varied: to connect theory and practice; to conduct classroom-based action research; to intensely study issues in inquiry-based teaching, coaching, and mentoring, constructivism, and assessment; to get involved in professional organizations at the local, state, and national levels; and to apply the vision and goals of the national standards to the classroom.

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In addition to what they learned in their study group, the Cleveland teachers joined local, state, and national organizations, and attended and presented at these organizations' conferences. The group was selected to be involved in a multi-state portfolio project focused on assessment. Most members have started study groups with other teachers. Journeys members continue in their professional growth and learning: "We believe that we have begun to discover the meaning of life-long learning" (Badders et al., 1996, p. 3).

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Strategy 10: Coaching and Mentoring

Coaching and mentoring are professional development strategies that provide one-on-one learning opportunities for teachers. Coaching is often thought of as a peer activity — support between teachers who have equal competence — while a mentor is an experienced professional who guides a colleague with less experience.

Traditionally, coaching focused on classroom observations and use of a preconference-observation-postconference cycle. Recently, the concept of coaching has broadened to include other activities such as co-planning instruction, developing materials, and discussing the impact of teacher behavior on students (Showers & Joyce, 1996).

Mentors can play the roles of teacher, coach, role model, sponsor, protector, and opener of doors. The literature on mentoring beginning teachers is substantial; research indicates that effective mentoring programs can lower the attrition rate for new teachers, significantly decreasing the length and trauma of their induction period into the profession (Newton, Bergstrom, Brennan, Dunne, Gilbert, Ibarguen, Perez-Selles, & Thomas, 1994).

Sometimes mathematicians can be mentors for teachers, helping them develop deeper understanding of the content and enabling them to insert examples of real-world applications in their lessons. On the other hand, it is important to recognize that experienced teachers are competent professionals whose observations are valuable sources of knowledge for other teachers.

The Strategy in Action

This strategy requires special skills in observation and communication. Sophisticated training programs are available to help coaches and mentors understand the principles of adult learning, conflict resolution, and the change process. While good coaches and mentors from any discipline can help teachers become better inquirers into the dilemmas of teaching, they can be of much greater assistance if they know the specific content being taught.

Coaching and mentoring are most successful when teachers agree that they will work on examining particular problems. Sometimes this is as focused as tallying the number and kinds of questions teachers ask of different students to understand gender or cultural biases. Other times the focus is more general, such as techniques used to manage materials.

Obviously, for coaching and mentoring to work, teachers need opportunities to interact with each other. Just having time for classroom observations without the chance to talk before and after defeats the purpose. While a novice teacher may pick up some tips by sitting in on a lesson, a follow-up discussion of what was done, why, and with what impact is critical for true understanding.

Because of the personal nature of coaching and mentoring, a climate of trust, collegiality, and continuous growth are absolutely necessary. The ability to fail and learn from failure, to acknowledge both strengths and weaknesses, and to build improvement strategies on both, is best acquired with the help of a "critical friend" (Costa & Kallick, 1993).

Building this level of trust can only happen if interaction occurs with some regularity, so that suggestions can be tried and reflections on their impact shared. Coaching and mentoring pairs need to build an understanding about each other's knowledge of teaching, learning, and content, and what each can do with students in classrooms. Administrators need to recognize the importance of mentoring and coaching relationships and to nurture the building of a learning community in the school (Garmston, 1987; Showers & Joyce, 1996).

Issues to Consider

Norms of isolation and privacy work against many teachers' willingness to open their classrooms to scrutiny. Acceptance of coaching is enhanced if initial observations focus on a nonthreatening question before moving to more challenging issues about teaching and learning.

Finding time for making and discussing classroom observations is a problem within a typical school schedule. Creative solutions include hiring a roving substitute for the day to relieve the observing teachers one after the other, rearranging planning times, team teaching, and taking advantage of administrators to work with students while teachers meet (Joyce & Showers, 1987).

Some people believe that mathematics teachers need assistance from outside their schools, delivered by trainers, program developers, and mathematicians. The critical and specialized knowledge that experienced teachers have — pedagogical content knowledge — is not valued (Shulman, 1987). Yet it is this very knowledge that helps teachers understand what their students need.

Teachers Empowering Teachers: Computers in Geometry Classrooms is a coaching and mentoring program at Saint Olaf College in Northfield, Minnesota. The project's main goal is to help geometry teachers develop the knowledge, skills, and confidence necessary to use computer-based tools in their classrooms (Wallace, Cederberg, & Allen, 1994). The project is designed around an expanding network

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model: from college instructors, the network expands to master high school geometry teachers, then to less experienced teachers, and finally to colleagues in each teacher's school. Experts at each level work closely with teachers in the next level, serving first as a mentor, then as a coach, and finally as a colleague. As coaches and mentors, teachers serve as classroom assistants, facilitators of discussion groups, instructors during workshop sessions, observers during classroom teaching, and collaborative peers during lesson development. They also conduct simulated classroom sessions where they model the teaching of geometry lessons that incorporate computers. Each level of the network provides unique opportunities for teachers to serve as mentors and coaches in these various roles.

Teachers Empowering Teachers
Computers in Geometry Classrooms
Saint Olaf College
1520 St. Olaf Avenue
Northfield, MN 55057
http://www.stolaf.edu

Strategy 11: Partnerships with Mathematicians in Business, Industry, and Universities

The types of partnerships between teachers and mathematicians working in business, industry, and universities are as diverse as the individuals involved. One form of partnership — teachers immersing themselves in the world of mathematics — has already been discussed (Strategy 2). The partnerships discussed here involve mathematicians coming into the world of the teacher: mathematicians serving as mentors; working side-by-side with teachers as resources for understanding content; participating in the design and evaluation of curriculum materials; or sitting at the table during strategic planning.

Partnerships for professional development are based on the assumption that the quality of mathematics teaching and learning is the responsibility of the entire community, not just the schools. Partnerships, to be effective, must truly be two-way exchanges. Mathematicians and teachers have equal but different roles to play. Their joint efforts are based on a mutual belief that each can make important contributions to the effort (Loucks-Horsley, Harding, Arbuckle, Murray, Dubea, & Williams, 1987).

What do the partners get out of these relationships? For teachers, working closely with mathematicians provides them with role models and real-world application of subject matter. They have the opportunity to learn more about how the mathematics processes work and are exposed to a different professional culture and a broader knowledge base.

For mathematicians, benefits include the opportunity to become familiar with the realities of a school system and to become advocates for quality mathematics education. They can examine their own teaching, becoming aware of how they model teaching strategies, especially whether they promote active learning. Truly collaborative partnerships move mathematicians away from the traditional roles they have played in public education — judges of math contests, expert speakers, and hosts for field trips — and into a more interactive sharing of their work with learners.

The Strategy in Action

In the past 10 years, more and more partnerships stress collaboration between teachers and mathematicians with the explicit purpose of teacher professional development. In their roles as content experts, mathematicians strive to help teachers build confidence in teaching mathematics. Mathematicians may present at workshops; work with teachers to increase their content knowledge; evaluate the mathematics accuracy of teaching materials; work with teachers to develop goals and classroom activities to achieve those goals; assist in writing grant proposals; provide access to equipment and materials; and invite teachers into research labs.

Regardless of the specific activities, both partners need to ensure that their involvement is consistent with the objectives of the mathematics program and does not undermine either implicitly or explicitly the existing curriculum. The partners also

must develop a history of shared experiences that, over time, build the trust and respect necessary for the high levels of commitment needed to improve mathematics teaching and learning.

Since the world of mathematicians is dramatically different from that of teachers, an understanding of both is essential. Mathematicians and teachers must feel an equal stake in the success of their partnerships, and they must be invested in quality professional development. Both partners must break out of their traditional roles (e.g., mathematicians as knowledge producers and teachers as translators of that knowledge) and develop new ones. To stay interested, partners must see significant benefits of being involved. When they do see results, they take credit as a team and celebrate their joint efforts.

People often underestimate the amount of time and energy it takes to collaborate with others, especially in activities as complex as professional development. Thus, there must be organizational support for the partners. If teachers are to be more than the passive receivers of someone else's professional development program, then school personnel must commit significant energy to planning, delivering, and following up on activities. Mathematicians also need flexibility in their own professional responsibilities to devote time to the partnership.

Partnerships do not thrive without visionary leadership. Because partnerships often are viewed as above and beyond the call of duty to participants who already have a full worklife, the motivating force of a leader is vital. A good leader keeps activities moving and coordinates people, timelines, and tasks so that everyone knows what is happening and the benefits are visible. Of course, within the partnerships, leadership needs to be shared by the mathematicians and the teachers.

Issues to Consider

While bringing teachers and mathematicians together can be a powerful learning experience, cultural and communication differences can be challenging. At the onset of a partnership, teachers and mathematicians need orientation to help them understand the realities of each other's worlds. Mathematicians need to understand student competencies and developmental learning. They need to focus on bringing a piece of what they do in their own world to their interactions with the teachers.

Sometimes, issues arise around expectations that mathematicians bring to the partnership: that they are there to "fix" the situation, believing the educational problems can be solved if only the teachers would listen to them. Some mathematicians see the school as an environment where they can identify a handful of young people interested in moving into their field, rather than a place where the knowledge of all can be increased. And, if these mathematicians teach through lecture, they will be less likely to value the constructivist approach to learning mathematics.

Mathematicians often face the obstacle of not receiving encouragement from their institutions to pursue relationships in settings outside of their normal working environments. They have conflicting demands to continue with research in the laboratory, publish journal articles and books, and make significant contributions to their fields.

Finally, teachers sometimes fear intrusion by outsiders, especially those viewed as the ultimate experts. Feeling the respect of mathematicians for their work as teachers goes a long way toward solidifying the relationship and ultimately benefiting students.

The effective use of Partnerships with Mathematicians in Business, Industry, and Universities is exemplified by the Kentucky K-4 Mathematics Specialist Program, which has established a network of 435 mathematics specialists in 143 districts and 25 private schools across Kentucky. The program's primary goals were to implement the recommendations of the NCTM Standards in elementary classrooms across the state and to provide opportunities for collaboration among university faculty, classroom teachers, and school administrators. Regional teams worked closely together to develop seminars to prepare teachers as mathematics specialists. The teams were

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composed of university mathematics educators, university mathematicians, classroom teachers, and school administrators. The program found these diverse teams to be highly effective. They found that the regional team members gained a mutual respect for each other. Mathematicians learned to appreciate the complex task of teaching elementary school. Teachers learned to appreciate the mathematical and pedagogical expertise of the university faculty as well as the depth of their mathematics and theoretical perspectives. The seminars were strengthened by the collaboration of persons with different backgrounds. The activities and information provided in seminars were mathematically and pedagogically sound and classroom tested (Bush, 1997, p. 174).

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Strategy 12: Professional Networks

Networks are "discourse communities" that enable teachers to meet regularly (either in person or electronically) to solve problems, consider new ideas, or reflect on specific issues in mathematics (Lieberman & McLaughlin, 1992). Sometimes networks are self-directed with the participants defining their own agendas; other times they are moderated by experienced facilitators who encourage the exchange of ideas within the community. Networks may develop through school-university collaborations; teacher-to-teacher or school-to-school linkages; partnerships with neighborhood organizations, teacher unions, subject-matter associations; and local or national groups.

Effective networks promote sharing of ideas with professionals in different environments. Creating an essentially new structure for teachers' involvement outside of their workplaces results in new norms of collegiality, a broadened view of leadership, enhanced perspectives on students' needs, opportunities to be both learners and partners in the construction of knowledge, and an authentic professional voice for teachers.

Networks also build the capacity of their members to identify and solve their own problems. Teachers develop a sense of confidence in their individual and collective ability to make improvements. Meaningful reform occurs best when an educational community works together toward common goals.

The Strategy in Action

Formal networks articulate specific goals, recruit members, and plan activities such as summer institutes and regular meetings, and coordinate electronic discussions or newsletters. In addition to drawing upon the expertise of network members, many formal networks also elicit contributions from experts in areas of interest to the network participants. For example, a network that is focused on making high school instruction relevant to students' futures might involve employers who can share information about the skills needed in the workplace.

Informal networks can also provide professional support. For example, middle school algebra teachers, who are often alone in their schools, may, through an informal network, share teaching materials and ideas. These informal networks should be recognized by the teachers' districts as legitimate professional development activities.

To be most effective, networks need to develop a high level of trust so that participants feel free to disclose information about what they think, how they teach, and what they need, and to take personal risks, such as being a critical friend with other members. Achieving this rapport takes time, but it should be a recognized goal from the very beginning of the network.

Networks need a purpose. The focus of the network might be broadly defined at first, giving members the opportunity to fine tune it. New interests and more com-

plex relationships may emerge through networking; however, the initial focus must be retained or the membership must declare that the purpose is shifting. If the intent of the network becomes unclear, it may become irrelevant.

Effective networks require leadership. In some formal networks, the designated leaders may be in organizations that have funding for network support. In informal networks, leadership may rotate, but is nonetheless critical to maintain momentum. Capable network leaders are visionary, are effective in a variety of contexts, and are comfortable with ambiguity yet knowledgeable about the focus of the network.

Effective networks also assign responsibility for monitoring progress. Because participants' needs change over time, it is important to keep tabs on whether the network is keeping pace. Asking members to comment regularly and suggest ideas for improvement can keep a network vital.

The endurance and effectiveness of a network are often directly related to its lack of complexity and the low cost of active participation. While some electronic networks may be able to handle large numbers of participants, networks that rely on personal interaction or direct contact with a trained facilitator need to remain small. With adequate resources, strategies such as tiered or multiple leadership can permit larger membership.

Issues to Consider

Sustaining effective networks can be difficult. Lieberman and McLaughlin (1992) discuss numerous issues that network organizers and participants need to address. One challenge they cite is that the network may draw teachers' loyalty and interest away from the school to the network itself. Consciously addressing this issue in discussions and activities within the network can help increase the likelihood that teachers will implement their new learning in their classrooms.

On the other hand, teachers in networks may feel ostracized within their own schools, by other teachers, the principal, or the administration. Some formal networks require that all teachers in a department within a school participate in the network. However, this imposes a requirement that is not always conducive to the trusting environment inherent in effective networks.

Network participants and organizers need to secure long-term support. This includes not only funding but also the establishment of structures to help ensure the long-term sustainability for the network, such as legitimate time for teacher participation and, when necessary, access to computers and other equipment needed to participate in the network.

Managing a network is a fundamental problem for both networks and their sponsors. The more popular the network, the greater the demand on its limited resources. It is easy to underestimate what it will take to maintain a network. This challenge may require restricting membership to a size appropriate to both resources and capacity to serve members well.

Some networks that are initiated by foundations, schools and university partnerships, or by national or local reform efforts come with their own agendas. This can result in a problem about who controls the network. Since the power of networks lies in their flexibility, their agendas are in a constant state of refinement. Sometimes, however, the partners with the money and/or status become uncomfortable as teachers are emboldened to take more control.

Most networks are formed around specific goals but as new responsibilities and roles emerge teachers often find themselves in roles they are unaccustomed to playing: political strategist, negotiator, policy maker, or conflict mediator. Networks need to address this issue and provide teachers with opportunities to take advantage of these new roles.

Professional Networks are in use as a professional development strategy in the Urban Mathematics Collaborative (UMC). Initiated by the Ford Foundation and involving some of the largest school districts in the nation, the purpose of the collaborative is to help teachers of mathe-

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matics address the poor performance of many inner-city students. The network connects urban teachers with one another, other users of mathematics, and individuals involved in mathematics education improvement. UMC exposes teachers to new ideas, providing them with information about how students learn mathematics and what mathematics should be taught. The network focuses considerable resources on the development of teacher leaders.

The success of the collaboratives rests on many of the important assumptions and critical elements noted in this section: teachers join the network voluntarily and with a commitment to improving their teaching; the network encourages teachers' use of new approaches in their classrooms through collegial support and feedback; the collaboratives create a community of learners sharing a common vision of mathematics education improvement; and the goals and agenda of the network are determined by the teachers themselves.

Urban Mathematics Collaborative (UMC) Project
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VEHICLES AND MECHANISMS

Strategy 13: Workshops, Institutes, Courses, and Seminars

Workshops, courses, institutes, and seminars are structured opportunities for educators to learn from facilitators or leaders with specialized expertise, as well as from peers. These professional development sessions usually occur outside the classroom and often bring together educators from different locations for common experiences.

Courses and institutes provide opportunities for participants to focus intensely on topics of interest over relatively long periods (weeks in the case of institutes, months in the case of courses). Workshops and seminars, on the other hand, tend to be offered for shorter periods and address more discrete learning goals, such as using a particular set of lessons or trying out a new assessment strategy. Workshops are characterized by hands-on activities while seminars tend to be more oriented to discussion of others' practice or research results.

The structures of workshops, institutes, seminars, and courses provide teachers with opportunities to connect with outside sources of knowledge in a focused way. Learning outside of the work environment allows deep study and practice. Teachers need time away from their classrooms to reflect, interact with other educators, and practice new techniques in safe settings.

A major question about this strategy is whether one size really can fit all. A well-crafted learning activity can indeed meet the needs of many learners. Although individuals each bring something different to the experience and inevitably take away something different, this structure assumes that many learners can benefit from the same experience.

The Strategy in Action

Courses are by definition ongoing, providing time for teachers to practice new ideas and behaviors and return to the next course meeting to reflect together on problems and successes. Although of a more limited duration, the best workshops, seminars, and institutes are designed to include a variety of modes through which learners can process information. These include journal writing, analysis of case studies, role playing, small group discussions, modeling lessons, engaging in problem solving, and creating classroom materials.

Leaders of effective workshops, institutes, seminars and courses communicate with participants about the goals of the learning experience. They receive input from learners before setting goals so the experience addresses the learners' needs. The facilitator also guides the participants' learning, often by being a primary source of expertise or bringing in other informa-

tion through readings, consultants, the participants' own knowledge, and structured experiences.

Workshops, courses, seminars, and institutes can use the "training" model, which has a strong research base (Joyce & Showers, 1988). This model includes several steps: explanation of theory; demonstration or modeling of a skill; practice of the skill under simulated conditions; feedback about performance; and coaching in the workplace.

Most workshops and seminars meet during regular school hours and require that a teacher have a substitute for the classroom. Teachers usually participate in courses and institutes during non-teaching time (such as the summer or evenings and weekends). A variety of incentives can be offered when teachers participate on their own time. In addition to stipends, teachers can be rewarded through special recognition or through graduate or professional development credit.

Issues to Consider

Research in teacher change reveals that a one-time workshop or seminar is unlikely to result in significant, long-term change in the practice of a teacher (Fullan, 1991; Joyce & Showers, 1988; Little, 1993). Rather, change requires multiple opportunities to learn, practice, and reinforce new behaviors. Thus, while a single workshop may be a good kick-off for learning and can result in new awareness on the part of participants, additional opportunities are needed for long-lasting change.

Ideally, one-time workshops and even long-term courses are combined with other strategies to enhance the learning experiences of the participants. For example, simply attending a workshop on mathematical pedagogy is insufficient to equip teachers to alter their practice. Teachers also need opportunities to translate their learning into practice (perhaps through modifying their curriculum — Strategy 5), implement the new knowledge (perhaps with coaching — Strategy 10), and reflect on their practices (perhaps through case discussions — Strategy 7). When the principles of effective professional development are incorporated into the design of workshops, institutes, courses, and seminars and then are combined with other strategies, the benefits for teachers are strengthened.

One example of the effective use of workshops for professional development is the Math Talk project at Children's Television Workshop. This project conducted workshops and follow-up sessions with teachers to help them use supplementary mathematics curriculum materials to address national standards. Teachers were offered the opportunity to participate in the workshops through the Eisenhower Regional Consortium in the Northeast. The sessions were led by knowledgeable mathematics educators who combined demonstrations of the materials and explanations of the mathematics content within the materials to prepare teachers to teach with Math Talk. Teachers shared their misconceptions about certain content (e.g., rules of probability or measuring area and perimeter), and the mathematics experts helped to deepen the teachers' understanding of the mathematics behind the classroom activities. Workshop leaders also helped teachers with their plans for introducing the materials in the classroom. During follow-up sessions, the teachers reported on their use of the materials, asked questions, and helped one another with plans for introducing more units. Again, the workshop leaders led discussions and demonstrations to increase the teachers' knowledge of mathematics content. Teachers also practiced using hands-on activities that they would reproduce in their classrooms. The cost of teacher substitutes was paid to the districts and the teachers were given stipends for some Saturday sessions. They also received professional development credit toward re-certification.

Children's Television Workshop
School Products
Attn: Katy Broomfield
1 Lincoln Plaza
New York, NY 10023
(212) 595-3456

To purchase Math Talk materials, call:
Great Plains National
(800) 228-4630

Strategy 14: Technology for Professional Development

Technology could be considered everything from paper and pencil to elaborate communication devices. Technology for professional development is defined here as an electronic means of either supporting the in-person professional developer or of providing professional development opportunities without a face-to-face facilitator. This section focuses on technologies that have emerged in the last 20 years, rather than more traditional ones, such as overhead and slide projectors.

What may immediately come to mind for the reader is the Internet and electronic mail. This section expands on these two systems and presents ways in which a variety of other technologies can be used to provide effective professional development experiences.

The Strategy in Action

Teleconferencing.
Teleconferences provide one-way, audio or video presentations to different remote sites. A presentation is made in a television studio, "uplinked" to a live satellite, and then delivered (downlinked) to other sites. Lectures, panel discussions, videotapes of classroom activities, or demonstrations are usually the subject matter. Often, written materials that accompany the presentation are made available to the downlinked sites, which are given a telephone number to call during the live presentation so that questions can be answered during the telecast.

Teleconferences are usually one-time activities that provide information to participants, often with some form of activity or discussion at each site following the telecast. This technology is rarely used for ongoing professional development and its main drawback is the lack of continuous interaction. However, one of its greatest advantages is that a large number of people can be reached at one time in a number of remote sites.

This medium is expensive to produce and send through a satellite, but the equipment required on the receiving end is less expensive. While probably not an option for most individual teachers, some school districts already have a satellite dish and can participate in this form of professional development with only a nominal participation fee.

Television and Interactive Television.
Pre-programmed television series have been aired for many years. The purpose of this type of programming is to provide a very large number of teachers with an ongoing course of study. Usually, viewers register with a program, are sent instructional materials, view the program, and conduct activities in their classrooms or read assigned materials. Some programs require that written materials be submitted by viewers. While inexpensive (teachers only need a television), the greatest drawback is the lack of interaction. To counter this disadvantage, some programs have added an electronic mail component so that viewers can develop online learning groups.

Interactive television, unlike one-way teleconferences or pre-programmed television programs, is a two-way system. Two or more remote sites are linked through cameras, and teachers can see and hear participants at other sites through a television. It is an expensive technology and its success often depends upon the quality of the equipment.

Telecomputing Courses.
Using only a computer and a modem, teachers can enroll in telecomputing courses. Most courses provide instruction via text. Activities are then conducted in the classroom, followed by online discussion. The advantage of telecomputing is that most programs use a conferencing software that allows for individual messages to be sent between the instructor and students and among students. There are also real-time discussions among all participants.

One of the disadvantages of these courses is that they are often composed of self-starters who are highly motivated to pursue professional learning on their own. Providers of these courses struggle with how to keep less involved participants from falling behind, how to combat the feeling of anonymity teachers may feel, and overcoming "technophobia" that keeps many teachers from participating.

Electronic Mail and Networking.
Electronic mail allows for a variety of interactions with peers. Listserves, bulletin boards, and chat rooms are all means of sharing ideas among teachers, other educators, and individuals with special expertise such as mathematicians.

One example of an electronic network is TEECH, Teacher Enhancement Electronic Communications Hall, out of TERC in Cambridge, Massachusetts. The TEECH Web site provides resources in the form of papers, electronic lectures, and databases on numerous topics in teacher enhancement. The network also provides various "modes" (ways to interact with the site): participation in discussion groups, conducting searches, reading or listening to lectures, or accessing a calendar of events.

Videotapes and Laser Videodiscs.
These technologies are most frequently used in face-to-face professional development experiences. Viewers watch teachers investigating mathematics ideas, experimenting with new teaching practices, and developing ways to study what their students are thinking. Many videos also include classroom episodes. Professional developers working with teachers use the videos and the accompanying resource books as vehicles for reflective discussion. One example is the Annenberg Video Library, which is listed in Section IV.

CD-ROMs.
This technology provides flexible access to a large amount of materials for use in teaching, learning, and designing professional development. CD-ROMs can contain print material, videotape footage, audio recordings, and other resources.

One example of a CD-ROM is being developed by teacher educators Magdalene Lampert and Deborah Ball (1995) for use with pre- and inservice teachers of mathematics. Currently, the materials developed at Michigan State University through the Mathematics and Teaching through HyperMedia Project use a hypermedia system. The original project field-tested a "collection of multimedia tools for exploring and constructing knowledge about mathematics teaching and learning in elementary school" (Hatfield & Bitter, 1994, p.109). The hypermedia system links audio and video records of mathematics lessons being taught to other material such as written student work, interviews with students, teachers' journal entries, observers' field notes, and lesson annotations.

Tools for Group Work.
GroupSystems, from Ventana Corporation, provides a computer-based support tool for facilitation of same-time, same-place, as well as same-time, different-place meetings. Participants are linked together through computers and the main GroupSystems program that is monitored by a facilitator. During a session, participants can switch from discussions to online group or individual work. GroupSystems' main feature is that the author of a comment can remain anonymous (even with participants in the same room), allowing the online discussion to focus on the comment and not the author.

The Ontario Institute for Studies in Education has developed a similar computer-based system for informed group decision making within a collaborative environment, Computer Supported Intentional Learning Environments (CSILE). CSILE and GroupSystems are only two examples of this type of technology, which has not been explored to its fullest as a tool in professional development.

Issues to Consider

The use of technology to provide or enhance professional learning for teachers has many advantages, some discussed above. Another advantage, noted repeatedly by providers of electronic mail, networks, and telecomputing courses, is that technology is largely neutral in regard to race, status, age, income, disability, and gender (Schmidt & Faulkner, 1989; Smith, 1996; Taylor & Smith, 1995). When communicating online, the only personal characteristic that is identifiable is gender, typically given away by a name. Technology also meets the needs of learners who are homebound due to health, family responsibilities, or personal preference.

The lack of face-to-face interactions is the most commonly noted disadvantage of the use of technology. Interestingly, several programs have found that participation increases when people online are anony-

mous (CCT Notes, 1995; Smith, 1996; Spitzer, Wedding, & DiMauro, 1994; Taylor & Smith, 1995). Discussions often delve deeper into a topic. Given the nature of online interactions, teachers sometimes feel less competition for time to "speak," since they can share their comments electronically at any time.

An unanticipated outcome of this "leveling" or lack of inhibition on the part of those using electronic communication is the quality control dilemma. Because all users have equal voice, their ideas take on an authority that may have little experience to support it. People with more time to communicate can appear to know more; those with more expertise but less time may not be recognized. Further, experienced moderators of telecommunications report that making critical comments or challenging ideas can often result in "shutting down" conversations rather than causing deeper thinking (Falk, personal communication).

There are other real disadvantages to using technology for professional learning. Lack of appropriate hardware, software, or technology can impede teachers' access to the medium. This is an important equity issue. Although technology improves access for some, the economically disadvantaged have less access.

Another important issue is participants' comfort level with technology. If teachers are expected to access electronic networks, they need to have time to learn how to use the technology, before they can move forward in meeting the goals of the experience. Ongoing technical assistance is essential if teachers are to make the most of professional development via technology.

Technology is being touted by many as a critical ingredient in education for the future. Although it clearly holds great potential, professional developers need to think carefully about when and where it is most appropriate, and how it can extend our abilities to create effective professional learning experiences.

The use of Technology for Professional Development is exemplified in the Mathematics Learning Forums Project, which conducts online seminars hosted by graduate faculty members of Bank Street College in New York City. These eight-week seminars offer K-8 teachers instruction on how to teach mathematics. Teachers connect to the seminar via the Internet at their convenience and interact with the faculty and other seminar participants. After each session, teachers try out new activities in their classes, then get help improving their practice through subsequent electronic conversations. The Forums are a partnership between Bank Street College of Education and the Education Development Center's Center for Children and Technology. They combine computer-based communication, print materials, and videotapes to help K-8 teachers reflect on and adopt new teaching practices consistent with the goals envisioned by the NCTM standards for improving mathematics instruction (Center for Children and Technology Notes, June 1995).

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Strategy 15: Developing Professional Developers

The strategy of identifying and developing professional developers has been used widely in mathematics improvement. When professional development was narrowly construed as training, this strategy was more commonly termed "train-the-trainer." Now, as professional development has broadened to include a variety of strategies to support professional learning, so too have the roles and attendant skills of those who would help professionals learn. "Train-the-trainer" has become "professionally develop the professional developer"!

As an organization considers its long-term professional development plan, the strategy described in this section is very important. Supporting local professionals to assume professional development roles has many benefits. It builds local capacity for ongoing development and can serve as a reward for teachers and other professionals who have the requisite skills, attitudes, and interest. Creating professional developers means the organization has an internal expert who can connect those in the organization to innovations happening outside through national and regional networking.

Ten years ago, there were few formal programs for professional developers. Most grew into their roles by implementing new instructional practices and sharing the good ones with colleagues, sometimes attending train-the-trainer workshops. The lack of a career path for these "home grown" staff developers often led them to leave their classrooms to become consultants. Increasingly, as school districts or other professional development initiatives seek to build local capacity for continuous learning, they are using the strategy of developing their own professional developers.

The Strategy in Action

The first step is to identify potential professional developers. One source is individuals who have had some other leadership experience, including those who have served as coaches or mentors, instructors or clinical faculty for university courses, or team leaders or department chairs in their schools. These experiences are likely to have broadened the individuals' perspectives beyond their classrooms and given them opportunities to develop effective ways of working with adults. Professional developers can also come from classrooms, especially good teachers whom others emulate.

No matter where they come from, those with the potential to become successful professional developers have certain attributes in common: they are open to change, credible with teachers, effective communicators, and have experiences and knowledge that are relevant to the teachers they will work with. They are self-confident, organized, and interact well with their peers. They have the time to engage in their own development and, ultimately, to work with others in a professional development role. Finally, they have deep knowledge of mathematics content.

Once the individuals have been identified, they need to master the program or knowledge base that will support others to change. Professional developers know the new techniques, can demonstrate them, have made them a routine in their teaching, and have evidence that they work with their students. This usually takes at least two rounds of practice or application, which may mean two years, before these teachers are able to teach and support others.

When the new professional developer is ready to begin, everyone must recognize that designing and conducting learning experiences for others is not a job that can be done after school and on weekends, if it is to be done right. For local professional developers to be used well, they need time released from regular classroom responsibilities.

There is no one prescription for developing the requisite skills of professional developers. Many colleges and universities now offer courses that address inservice education, coaching, collaboration, and change management in schools. Some institutions (e.g., the University of Maryland) offer doctoral level training in staff development. More commonly, school-based professional developers develop the necessary skills through workshops, many of which are offered by the Association for Supervision and Curriculum Development and the National Staff Development Council, and by continuing their development in their particular area of expertise (e.g., mathematics education, assessment, action research). They are involved in self-study and networks, and are mentored by more experienced staff developers. They read journal articles, attend training or conferences, and join online networks.

Professional developers cannot work in isolation. Collaboration among professional developers leads to many positive outcomes: access to the latest findings from research, knowledge of effective programs, and awareness of the quality of training programs and curriculum.

Through national and regional networking, professional developers gain access to these important resources and continue their own development.

Issues to Consider

Some people believe that professional development would be better left to consultants and outside experts. They argue that teachers should focus on good teaching and that professional developers require a different set of skills than good teachers. However, as teachers are expected to align their practices with one another and collaborate on new initiatives, they will need the skills of good professional developers.

Quality control is a key concern as schools and projects develop professional developers from among the teaching staff. Novice professional developers are unlikely to be as effective as the expert consultant who has been honing skills for years. They need encouragement, observation, and coaching as they take on their new roles. Pairing a new professional developer with a veteran is one strategy for ensuring quality. Engaging professional developers in debriefing sessions after they conduct workshops, model lessons, or work with a team helps increase their effectiveness. Feedback from participants in professional development activities can be used to assess program quality and make continuous improvements.

It is said that it is difficult to be a prophet in your own land. As teachers become professional developers they also need to establish their credentials so that they have the respect and support of their colleagues. The professional developer needs to juggle schedules, bring along resistant staff members, negotiate with school administrators and the community for resources and support, and stay current in areas of expertise. These demands, coupled with a teaching or administrative position, can lead to the professional developer becoming overextended and overwhelmed. Although developing local staff who have the expertise and abilities of professional developers is a beneficial strategy, these individuals need support to balance their multiple roles.

An initiative that focuses on developing teachers as professional development leaders is the Leadership for Urban Mathematics Reform (LUMR) project, created by the Education Development Center in collaboration with the Urban Mathematics Collaboratives (UMC) and their local school districts. LUMR is developing teacher leaders in urban communities at six UMC sites across the country in an effort to improve mathematics education. The project provides leadership training for teams of middle and high school teachers from these sites. Teachers attend three-week summer leadership institutes, receive follow-up support throughout the year, and technical assistance in their outreach efforts. A critical component of LUMR is the inclusion of district administrators on the leadership teams. Each team develops a plan that promotes improvement of mathematics education, provides district support, and facilitates teacher leadership.

Leadership for Urban Mathematics Reform (LUMR) Project
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Successful Programs

Connected Mathematics Program
Elizabeth City, North Carolina, Middle School

Located in rural Eastern North Carolina, Elizabeth City Middle School (ECMS) is implementing a new curriculum program with a strong professional development component. The school has been a pilot site for Connected Mathematics Program (CMP), a rigorous mathematics curriculum funded by the National Science Foundation and available from Dale Seymour Publications. This program illustrates the interrelated use of several strategies for professional development including curriculum implementation, curriculum adaptation and development, and coaching and mentoring. ECMS is part of the Elizabeth City-Pasquotank Public Schools, which has a total enrollment of 6,247 students in 11 schools; 60 percent qualify for free or reduced price lunches.

In agreeing to pilot the implementation of the CMP curriculum, the teachers of ECMS became essential partners with the CMP authors. For three years, the teachers have met regularly to discuss strategies for adapting and implementing the curriculum.

Susan Friel, one of the developers of CMP, has been working closely with ECMS throughout the pilot study. ECMS teachers work with the other authors and pilot schools to help rewrite the curriculum during summer meetings. The input from this rural school has proved to be invaluable, and the intensive analysis of the curriculum has led the teachers to a much deeper understanding of mathematics content and teaching strategies.

In addition, Friel and the ECMS staff have been experimenting with video coaching. Teachers think of ways that they can launch mathematics problems in their classes and then videotape the results. Then, in a video conference, teachers, the assistant principal, and staff from the University of North Carolina view a tape of a teacher conducting a lesson and make a collective decision about what worked and how that can be built upon. The video conferences allow teachers to think of different ways that they can pose problems and how they can implement new strategies. These conferences led to the development of a library of successful teaching lessons, so that new teachers can get an idea of how to best use the curriculum.

As a result of these efforts, ECMS has seen improvements in student achievement. Mathematics test scores have risen. In addition, the CMP emphasis on problem-based learning has led to improved test scores in subjects such as reading and writing, in addition to mathematics. Another benefit to the students and staff is that mathematics is now integrated with the other subjects. Children are now able to identify patterns and gain a deeper understanding of what they are learning. CMP has allowed students to apply what they learned in mathematics to other subject areas.

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Delaware Teacher Enhancement Partnership

New Castle, Delaware, Middle School

New Castle Middle School is in the Colonial School District, which serves an urban student population with an ethnic composition that is 69 percent white, 28 percent African American, and 3 percent other minorities. A major challenge in the district is student mobility: in any given year, one of three students changes schools. In addition, 74 percent of students come from disadvantaged families. New Castle Middle School serves a high percentage of city students, which contributes to significant social and economic problems in the school.

New Castle Middle School was selected to serve as an implementation center for the Delaware Teacher Enhancement Partnership (the Partnership), a project funded by the National Science Foundation (NSF) through the University of Delaware. The Partnership was designed to deepen teachers' mathematical content knowledge and pedagogic skills and to assist them in developing and implementing curricula based on national standards from the National Council of Teachers of Mathematics (NCTM) and on Delaware's new mathematics content and performance standards.

The Partnership combined a number of the techniques described in the Strategies for Professional Development section of this publication. Strategy 13, Workshops, Institutes, Courses, and Seminars, was a key component. The program began with an eight-day Eisenhower-funded pilot workshop for teachers. Activities in subsequent summers included two- or three-week workshops, one- or two-day Leadership Conferences for administrators and resource teachers, and special activities for Minority Leadership teachers.

Strategy 1, Immersion into Solving Mathematical Problems, was a major technique in the professional development activities for teachers. Sessions were designed around "situations," defined as rich mathematical tasks that elicit new mathematical content and problem-solving strategies. Veteran middle school mathematics teachers were constantly required to stretch their mathematical skills. The result was a greater appreciation of what many students experience as learners in the mathematics classroom. The teachers also developed a greater understanding of the need to move away from traditional teaching practices and to employ new techniques.

Graphing calculators and computer technology (Strategy 14, Technology for Professional Development) were used as catalysts to change both how mathematics is taught and what mathematics is taught. Teachers worked in groups, reflected on problem-solving strategies and the new mathematics involved, formalized the mathematics, and developed related lessons appropriate for their grade levels.

In the first three years of the project, Partnership staff worked one-on-one with middle school teachers in their classrooms. Teachers piloted lessons with their students (Strategy 5, Curriculum Development and Adaptation) and shared results with their colleagues (Strategy 10, Coaching and Mentoring).

In the last two years of the project, the focus shifted toward statewide dissemination. Using Strategy 15, Developing Professional Developers, Partnership staff and teacher leaders throughout Delaware collaborated with New Castle Middle School teachers to plan and present four, three-hour workshops for middle school teachers and four, 15-hour mini-courses for middle and high school teachers.

Since the Partnership focused on enhancing teacher content knowledge, pedagogical content knowledge, and curricular knowledge, Partnership staff developed and administered surveys to track changes in these areas. Teachers reported the greatest increases in content knowledge in the areas of probability, combinatorics, and discrete mathematics. The

greatest changes in teaching were reported in the areas of patterns/functions, algebra, and number relationships. Although the Partnership focused on professional development, student test scores rose from being near the bottom of the state before the project to reaching the median after the new teaching techniques were implemented.

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Professional Development Initiative

San Francisco, California, Unified School District

A Program Honored by the U.S. Department of Education's National Awards for Model Professional Development

The San Francisco School District serves approximately 64,000 preK-12 students in a major urban community. The population is diverse: 48 percent of students are Asian or Pacific Islander, 20 percent Hispanic, 17 percent African American, 13 percent white, and 1 percent Native American. Educating students for whom English is a second language is a major challenge: 30 percent of students have limited English proficiency; 39 languages are spoken. Ten percent of students receive special education services, and 59 percent qualify for free or reduced-price lunches.

Another challenge for the district is staffing. Each year, 200 new teachers must be hired. Some 35 percent of all teachers in the district have less than four years of experience. This situation will be exacerbated in the 1998-99 school year when more than 450 new teachers will be needed to respond to a state mandate to reduce class size. The district's reliance on large numbers of novice teachers served as a catalyst for creation of its Professional Development Initiative.
A number of the 15 Strategies for Professional Development described in this publication are employed throughout the Initiative. For example, in addition to providing an orientation for beginning teachers, the district encourages teachers to join the Beginning Teachers Support and Assessment Program (BTSA), a state initiative that provides novice teachers with an extended mentoring relationship with master teachers in the district (Strategy 10, Coaching and Mentoring).

The framework for the Professional Development Initiative for all teachers combines centralized activities with site-based initiatives. Each school is asked to analyze a broad range of student achievement data (Strategy 8, Examining Student Work and Thinking, and Scoring Assessments), rethink the curriculum, and create a plan that connects improvement activities with professional development plans (Strategy 5, Curriculum Development and Adaptation). For example, each of the 25 professional development "model schools" presents a preliminary plan to the others for review. This critical feedback is used by the planning committees in each school to refine their improvement plans. This provides an opportunity for teachers in all the schools to collaborate and share resources (Strategy 12, Professional Networks).

Eight days are set aside in the school year for professional development. The district plans a summer institute, multiple follow-up sessions, and on-site activities (Strategy 13, Workshops, Institutes, Courses, and Seminars). Individual schools are also expected to engage in professional development activities beyond these non-student days. The schools use a variety of creative ways to allot time for these activities, and many professional development techniques are employed, including Strategy 6, Action Research.

The K-8 Mathematics Initiative is a good example of the way in which professional

development is handled in the district. During the summer, a team of 200 teachers and administrators attended an institute focusing on such topics as the new mathematics curriculum, instructional strategies for Limited English Proficient students, and improvement strategies for students scoring in the bottom quartile. This team subsequently planned and delivered three district-wide professional development days for teachers, paraprofessionals, principals, and parents. Additional parent/family sessions were offered at schools during the evenings and on Saturdays. Teacher leaders from each school facilitated site-based follow-up sessions on such issues as family math, managing manipulatives, planning a standards-based math program, and assessing student growth (Strategy 15, Developing Professional Developers).

Another important component of the Professional Development Initiative is use of Strategy 11, Partnerships with Mathematicians in Business, Industries, and Universities. For example, teachers working in sixth through eighth grade mathematics have formed on-going relationships with the Bay Area Mathematics Project, San Francisco State University, and the University of California, Berkeley.

Test scores for reading and math on the California Test of Basic Skills have been used to show the impact of the Professional Development Initiative. These data show significant growth for all students in both areas for three consecutive years. Moreover, students attending "focus schools" with an emphasis on math and/or literacy show more than a year's growth for a year's instruction.

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QUASAR (Quantitative Understanding: Amplifying Student Achievement and Reasoning)

Portsmouth Middle School, Portland, Oregon

Portsmouth Middle School, a large, urban intermediate school in the Portland, Oregon, Public School District, serves approximately 550 students in a culturally diverse area of the city. Forty-nine percent of the students qualify for free or reduced-price lunches.

Teachers at the school decided to adopt Visual Mathematics (VM) after one teacher participated in a National Science Foundation curriculum development project at Portland State University. (Bennett, A.B. and Foreman, L. 1989, 1991. *Visual Mathematics Course Guide, Volume 1 and Volume 2: Integrated Math Topics and Teaching Strategies for Developing Insights and Concepts.* Salem, OR: Math Learning Center).

Portsmouth teachers found VM to be a challenging and engaging mathematics curriculum for students in middle school. Intensive professional development to support the new curriculum was provided through the school's participation in QUASAR, a Ford Foundation program implemented by the University of Pittsburgh to support and study the utilization of enhanced mathematics instructional programs in disadvantaged communities.

As participants in QUASAR, all four Portsmouth math teachers received summer training to develop a visual approach in their mathematics instruction; they also participated in monthly, full-day staff meetings (Strategy 1, Immersion into Solving Mathematical Problems). The major shift in instructional focus required that the teachers develop new skills, behaviors, and beliefs. As they learned to construct their own solutions to problems, they acquired new mathematical knowledge and gained self-confidence.

QUASAR activities provided opportunities for participants to share ideas and concerns regarding the use of new programs and practices. This ongoing network of professional colleagues enabled the teachers to explore and discuss topics related to the new curriculum (Strategy 12, Professional Networks). By sharing infor-

mation, pursuing common goals, and solving problems as a group, staff members learned from one another (Strategy 10, Coaching and Mentoring).

Portsmouth staff realized that the instructional changes required in implementing the VM curriculum were complex and could not be made without careful planning. Funding from QUASAR provided time for the staff to work on a schoolwide approach for mathematics instruction. Changes to be incorporated at the classroom level were determined by the teacher team; some instructional practices were used by all teachers, and others were modified to meet the needs of each teacher.

Each QUASAR site has developed its own design and implementation plan, so there is variation across sites with respect to curricula, teaching strategies, and approaches to teacher professional development. Financial and technical assistance has been provided through the project headquarters at the University of Pittsburgh's Learning Research and Development Center (Strategy 11, Partnerships with Mathematicians in Business, Industry, and Universities). Project staff have also systematically collected data at participating schools to monitor the processes and outcomes at each site.

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Teaching to the Big Ideas: Developing Mathematical Ideas

Northampton, Massachusetts, Public Schools

The Northampton Public Schools serve 3,000 students: 80 percent are white, 12 percent Hispanic, 5 percent Asian, and 3 percent African American. Special education services are provided to 18 percent of students, and 23 percent receive free or reduced priced lunches.

Recently, the district has been involved in revising the local curriculum to align it with the new Massachusetts Curriculum Frameworks. In mathematics, the Frameworks mandate a shift to math literacy in which students learn to solve problems and understand concepts as well as do computations.

The district realized that meeting the challenge would require significant professional development for elementary and middle school teachers. The goal was three-fold: (1) to give teachers a deeper understanding of mathematical principles thereby giving them confidence to depart from text-based teaching; (2) to demonstrate new instructional techniques that encourage youngsters to design individual strategies for solving math problems; (3) to help teachers learn to listen to, follow, and assess students' mathematical thinking.

Two Northampton teachers, Margie Riddle, a fourth grade teacher at Bridge Street School, and Nancy Dostal, a sixth grade teacher at John F. Kennedy Middle School, have taken leadership roles in the district's efforts to meet these goals. With the support of Eisenhower Professional Development funds from the U.S. Department of Education, Riddle and Dostal became involved in Teaching to the Big Ideas, a program developed through a collaboration of the Education Development Center (EDC), the Technical Education Research Centers (TERC), and SummerMath for Teachers at Mount Holyoke College. Program participants became involved in a number of the 15 Strategies for Professional Development described in this publication.

In addition to becoming immersed in mathematical problem solving (Strategy 1), participants in Teaching to the Big Ideas learned to examine their own students' work and thinking (Strategy 8). As the teachers wrote descriptions of their interactions with their students, program staff and the teachers themselves realized how these descriptions could be used to help other teachers examine their own practice (Strategy 7, Case Discussions). The

result of four years of collaborative work was Developing Mathematical Ideas, a two-volume professional development package consisting of a Casebook and a Facilitator's Guide.

For Riddle and Dostal, the next step was to become involved in a program funded by the National Science Foundation (NSF) to support them in becoming teacher leaders (Strategy 15, Developing Professional Developers). They were then prepared to present the materials they had helped create to their colleagues in the Northampton school district.

The first year, 15 Northampton teachers attended seminars (Strategy 13) that helped them to explore mathematical ideas and to analyze their own students' mathematical thinking. The process of observing carefully and writing thoughtful descriptions of how their students solved problems captured the teachers' imaginations. Through discussion, they discovered how they could build on student ideas and use the resulting dialog as an integral part of mathematics instruction.

Although the teachers received graduate credit for their participation in the seminars, Riddle and Dostal obtained funding to provide each teacher with a small stipend as well. This compensation increased individual commitment to the program.

The second year, an additional 15 teachers signed up for the program, but 10 members of the original group felt strongly that they wanted to keep on learning together (Strategy 9, Study Groups). With leadership from among the group and combined funding from a grant from the Northampton Education Association and other local sources, the teachers continue to meet to discuss their observations of their students' mathematical thinking. They are writing their own book of cases to illustrate their learning.

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Wilton, Connecticut, School District

A Program Honored by the U.S. Department of Education's National Awards for Model Professional Development

The Wilton, Connecticut (PreK-12) School District serves a predominately professional/managerial community with a high percentage of commuters to nearby New York City. This affluent suburban area has a high concentration of college educated residents; there are high community expectations for education, together with a strong local support for the continuing professional development of teachers. The district comprises five schools with an enrollment of 3,100 students: 94 percent are white, and only 5 percent qualify for free or reduced price lunches.

Three factors were critical to the creation of the professional development model currently in place in Wilton:

1. A professional development plan was developed in 1990 that aligned a series of district-sponsored activities to district goals. Math and science were the areas of initial emphasis.

2. Wilton schools serve a community with very high expectations for education. As a consequence, both standards and rewards reflect the competitive nature of the surrounding communities. The district fosters an ethic of continuous personal improvement. Teaching positions in the Wilton schools are highly contested. There were more than 800 applicants last year.

3. A lengthened workweek, moving from 37.5 to 40 hours, reflects a commitment to the importance of ongoing professional development. It also creates a means to sustain professional development activities across the school year.

School Planning Teams (comprising teachers, administrators, and parents) develop school improvement plans that are driven by four factors: district goals, curricular needs, student assessment data, and teacher performance needs. Historically, two or three initiatives receive attention for two or three years, resulting in a series of specific in-house workshops focused on improving teacher effectiveness.

In addition, a District Professional Development Committee (comprising teachers, administrators, and parents, and chaired by a full-time teacher holding the title "Instructional Leader for Professional Development") develops the district-sponsored activities based on a district needs assessment survey and discussions concerning best practice. This district committee plans the Professional Development Day, held in August each year. (Topics in 1997 included technology, reading and writing across the curriculum, school climate, inclusion, student assessment, and learning styles to motivate students.) The committee also plans a series of high interest strands addressed throughout the year.

A bimonthly newsletter, distributed by the district administrator for professional development, lists all the conference and workshop opportunities available in the state and beyond. Time for these activities is created by banking hours in designated months for professional development. No school or district meetings are scheduled during the months of October, January, and April. Consequently, the district has been able to schedule multiple workshops each week during these three months. Professional development has included the training of new teachers in current programs, workshops for teachers in new curriculum, and the opportunity for individual schools to explore those areas of greatest importance to them.

The district supports a trainer-of-trainers approach to capacity building: instructional leadership is encouraged in the district. More than 40 teachers currently hold instructional leader roles (e. g., grade-level or cross-grade team leaders, curriculum coordinators, and special program directors) in addition to their regular teaching responsibilities (Strategy 15, Developing Professional Developers).

Nearly 60 teachers have completed the state-sponsored BEST program, which qualifies them to be mentors of new teachers. New teachers are required to successfully complete this program in order to receive a provisional certificate. The BEST program involves the veteran and new teacher in the areas of peer coaching, team teaching, and using instructional resources (Strategy 10, Coaching and Mentoring). All teachers in the district are required to report back to their peers the connection between the school/district improvement plan and what they learned from each professional development activity they attend. This includes sponsored activities such as sabbaticals, conferences, workshops, and distance learning (any or all of which might be used towards Continuing Educational Units).

An analysis of test data has been the primary catalyst for professional development activities. Three questions have been asked concerning both state and national tests: (a) How does the district compare nationally with similar suburban districts and independent private schools? (b) What are the district's strengths and weaknesses in each grade level as they reflect on curriculum? and (c) What is the growth of each individual in each subject area? Math emerged as an area of concern, and after much discussion, the district adopted the University of Chicago School Math program. Following extensive professional development, including sending a team to work for a week at the University of Chicago with the program developers, the program has been introduced through the grades (Strategy 3, Curriculum Implementation). Last year the high school SAT math scores were the highest in Connecticut, and eighth grade math students ranked first in the state on the Connecticut Mastery Test.

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Woodrow Wilson Elementary School, Manhattan, Kansas

A Program Honored by the U.S. Department of Education's National Awards for Model Professional Development

Woodrow Wilson is one of 13 district schools in Manhattan, Kansas, a small university town (Kansas State University) surrounded by rural communities. Wilson, a K-6 school with 320 students, has the following demographic characteristics: 80 percent are white,15 percent are African American, 44 percent qualify for free or reduced price lunches and 30 percent receive special education services.

Three factors were critical to the development of the professional development model currently in place at Wilson:

1. The Quality Performance Accreditation (QPA) initiative adopted by the State Board of Education holds schools accountable for demonstrating student progress and mandates both site-based councils and school improvement plans. The QPA also requires a professional development component that must connect these activities with their impact on instructional strategies. This state initiative served to facilitate site-based decision making and focus thinking on individual school improvement strategies.

2. Three teachers focused their efforts on directing the faculty to reflect on the meaning and subsequent improvement of low student scores (initially) in fourth-grade math and science. Following a Summer Magnet School for mathematics and problem solving (involving voluntary participation by students and teachers), teachers in all grades embarked on a year-long study of ways to implement the National Council of Teachers of Mathematics (NCTM) standards school-wide (Strategy 1, Immersion into Solving Mathematical Problems; Strategy 8, Examining Student Work; Strategy 9, Study Groups).

3. Wilson was invited by Kansas State University (KSU) to become a Professional Development School. This initiative involved a number of components that served to focus the energy of the Wilson faculty on developing a plan for professional development and raising questions about the ways to improve student performance in the targeted areas. For example, a Wilson teacher was appointed a Clinical Instructor, with KSU supporting her half time out of the classroom; KSU faculty worked alongside several Wilson teachers with preservice and inservice teachers; KSU students, working alongside Wilson teachers, sponsored after-school clubs focused on math and science, which extended the learning time for students (Strategy 11, Partnerships).

The content of the school improvement plan is developed by teachers after analysis of student achievement data and a survey requesting teachers' priorities for professional development. Summer study groups and action research projects fuel this discussion and planning. Teachers use a combination of two 90-minute blocks of time each month (the time is recovered for professional development by reducing monthly faculty meetings from four to two), as well as creative use of KSU students and selective use of substitute teachers to craft opportunities for professional development activities. An important time for teachers to practice instructional innovations and to do peer observations is created by the after-school clubs designed around math and problem solving. This is a volunteer activity for teachers and KSU students (Strategy 6, Action Research; Strategy 9, Study Groups; Strategy 10, Coaching and Mentoring).

The Clinical Instructor (CI) is a key actor in this professional development plan. Released half time from the classroom (with funding from the KSU Professional Development School initiative), the CI facilitates the activities, which have been focused on math and science problem solving. In addition, the CI has coordinated field experiences in the school, taught university seminars and math and science methods courses, and mentored preservice and inservice teachers. In particular, the Wilson faculty has focused on problem solving in math, hands-on science, collaboration and networking, and raising expectations concerning students.

The professional development activities instituted by the Professional Development Committee at Wilson are forwarded yearly to the District Professional Development Council (comprising teacher representatives from each school, administrators, and central office personnel). Here school plans are assessed for their incorporation of district and state goals and for their efficient use of professional development funds. The District Staff Development Office offers support primarily in the areas of evaluation and assessment, and "capacity building workshops" (e.g., performance assessment, integrated curriculum, collaborative teaching, and development learner outcomes). A trainer-of-trainers model is used (Strategy 15, Developing Professional Developers). The Manhattan District is an active member in the KAW Valley Inservice Consortium, and in the "writing and performance assessment consortiums" of KWAC and KPAC.

Wilson has used a combination of Kansas assessment tests, curriculum tests, and performance-based tests to monitor the impact of their work in math and problem solving on student achievement. They have posted large gains on the Kansas math tests (especially for girls).

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SECTION IV

Technical Assistance Providers and Additional Programs

Sources of Technical Assistance

Eisenhower National Clearinghouse, Eisenhower Regional Consortia, and Regional Laboratories.

The National Network of Eisenhower Regional Consortia and Clearinghouse work together for the improvement of mathematics and science education. Along with the Regional Labs, NNERCC is funded by the U.S. Department of Education. ENC is a source for information about curriculum materials and professional development. The Consortia were created to provide technical assistance and professional development opportunities on topics important to their regions and the nation. The Labs provide many of the same services for all subject areas and are involved in education research and development.

National Clearinghouse

Eisenhower National Clearinghouse (ENC)
The Ohio State University
1929 Kenny Road
Columbus, OH 43210-1079
(800) 621-5785
(614) 292-7784 / Fax: (614) 292-2066
E-mail: info@enc.org
http://www.enc.org

Appalachia Region

States Served: Kentucky, Tennessee, Virginia, West Virginia

Eisenhower Regional Math/Science Consortium at AEL
1700 North Moore Street, Suite 1275
Arlington, VA 22209
(800) 624-9120
http://www.ael.org/eisen/

Appalachia Educational Laboratory, Inc. (AEL)
1031 Quarrier Street
PO Box 1348
Charleston, WV 25325
(800) 624-9120
(304) 347-0400 / Fax: (304) 347-0487
http://www.ael.org/

Far West Region

States Served: Arizona, California, Nevada, Utah

WestEd Eisenhower Regional Consortium for Science and Mathematics Education
730 Harrison Street
San Francisco, CA 94107-1242
(415) 241-2730 / Fax: (415) 241-2746
http://www.wested.org/werc/

WestEd
730 Harrison Street
San Francisco, CA 94107
(415) 565-3000 / Fax: (415) 565-3012
http://www.wested.org/

Mid-Atlantic Region

States Served: Delaware, Washington DC, Maryland, New Jersey, Pennsylvania

Mid-Atlantic Eisenhower Consortium for Mathematics and Science Education
Research for Better Schools
444 North Third Street
Philadelphia, PA 19123
(215) 574-9300 / Fax: (215) 574-0133
http://www.rbs.org/eisenhower

Laboratory for Student Success (LSS)
933 Ritter Annex
13th and Cecil B. Moore
Philadelphia, PA 19122
(215) 204-3001
http://www.temple.edu/LSS/

Mid-continent Region

States Served: Colorado, Kansas, Missouri, Nebraska, North Dakota, South Dakota, Wyoming

Eisenhower High Plains Consortium for Mathematics and Science
2550 South Parker Road, Suite 500
Aurora, CO 80014
(800) 949-6387
(303) 743-0990 / Fax: (303) 337-3005
http://www.mcrel.org/hpc

Mid-Continent Regional Educational Laboratory (McREL)
2550 S Parker Road, Suite 500
Aurora, CO 80014
(303) 337-0990 / Fax: (303) 337-3005
http://www.mcrel.org/

North Central Region

States Served: Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin

Midwest Consortium for Mathematics and Science Education
1900 Spring Road, Suite 300
Oak Brook, IL 60521-1480
(630) 571-4700 / Fax: (630) 571-4716
http://www.ncrel.org/msc/msc.htm

North Central Regional Educational Laboratory (NCREL)
1900 Spring Road,
Suite 300
Oak Brook, IL 60521
(630) 571-4700 / Fax: (630) 571-4716
http://www.ncrel.org/

Northeast and Islands Region

States / Areas Served: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont, Puerto Rico, Virgin Islands

Eisenhower Regional Alliance for Mathematics and Education Reform
TERC
2067 Massachusetts Avenue
Cambridge, MA 02140
(617) 547-0430 / Fax: (617) 349-3535
http://www.ra.terc.edu

Lab at Brown University Education Alliance (LAB)
222 Richmond Street, Suite 300
Providence, RI 02903
(800) 521-9550
(401) 274-9548 / Fax: (401) 421-7650
http://www.vlab.brown.edu/

Northwest Region

States Served: Alaska, Idaho, Montana, Oregon, Washington

Science and Mathematics Consortium for Northwest Schools
Columbia Education Center
171 NE 102nd Avenue
Portland, OR 97220-4169
(503) 252-4999 / Fax: (503) 252-4866
http://www.col-ed.org/smcnws/

Northwest Regional Educational Laboratory (NWREL)
101 SW Main Street, Suite 500
Portland, OR 97204
(800) 547-6339
(503) 275-9500 / Fax: (503) 275-9489
http://www.nwrel.org/

Pacific Region

States / Areas Served: American Samoa, Commonwealth of the Northern Mariana Islands, Federated States of Micronesia (Chuuk,Kosrae, Pohnpei, Yap), Guam, Hawaii, Republic of the Marshall Islands, Republic of Palau

Pacific Mathematics and Science Regional Consortium
Pacific Resources for Education and Learning
828 Fort Street Mall, Suite 500
Honolulu, HI 96813-4321
(808) 533-6000 / Fax: (808) 533-7599
http://prel.hawaii.edu/math-science/

Pacific Resources for Education and Learning (PREL)
828 Fort Street Mall, Suite 500
Honolulu, HI 96813
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Southeast Region

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Eisenhower Consortium for Mathematics and Science Education at SERVE
345 South Magnolia Drive, Suite E-22
Tallahassee, FL 32301
(850) 671-6033 / Fax: (850) 671-6010
http://www.serve.org/Eisenhower/

SouthEastern Regional Vision for Education (SERVE)
PO Box 5367
Greensboro, NC 27435
(800) 755-3277
(910) 334-3211 / Fax: (910) 334-3268
http://www.serve.org/

Southwest Region

States Served: Arkansas, Louisiana, New Mexico, Oklahoma, Texas

Southwest Consortium for the Improvement of Mathematics and Science Teaching
211 East Seventh Street
Austin, TX 78701-3281
(512) 476-6861 / Fax: (512) 476-2286
http://www.sedl.org/sedl/scimast.html

Southwest Educational Development Laboratory (SEDL)
211 East Seventh Street
Austin, TX 78701
(512) 476-6861 / Fax: (512) 476-2286
http://www.sedl.org/

Other Technical Assistance Providers

American Association for the Advancement of Science (AAAS). Washington, D.C. (202) 326-6400.

Association for Supervision and Curriculum Development (ASCD). Alexandria, VA (703) 549-9110.

Center for Case Studies in Education. Pace University, Pleasantville, NY (914) 773-3879.

Cognitively Guided Instruction Project. University of Wisconsin at Madison, WI (608) 263-4265.

Distance Learning Resource Network (DLRN). Technology in Education Program, WestEd, San Francisco, CA (510) 587-7304.

Developing Mathematical Ideas Institute. Education Development Center, Newton, MA (617) 969-7100.

Great Explorations in Mathematics and Science. Lawrence Hall of Science, University of California, Berkeley, CA (510) 642-9635.

GroupSystems, Ventana Corporation, Tucson, AZ (520) 325-8228.

Industry Initiatives for Science and Math Education (IISME). Lawrence Hall of Science, University of California, Berkeley, CA (415) 326-4800.

OTHER PROGRAMS

This section contains brief descriptions and contact information for additional professional development programs for teachers in grades K-8.

The Algebra Project

The Algebra Project is an innovative curriculum that uses real-life experiences and examples to help inner-city and rural students gain a rich understanding of mathematics. Training for teachers introduces new curriculum materials and teaching strategies and assistance in implementing the use of concrete experiences in developing mathematical concepts. This project is being used in school districts across the country, including Chicago, Atlanta, and rural districts in the Mississippi Delta area. Parents and community organizations have been key to implementing this project and providing additional classroom support to teachers.

Contact:
Bob Moses, President
The Algebra Project, Inc.
99 Bishop Allen Drive
Cambridge, MA 02139
(617) 491-0200 / Fax: (617) 491-0499
E-mail: ben.moynihan@bbs.serve.org

The Math Mentor Project

This project was created for teachers of kindergarten through eighth grade in schools with large minority and underserved populations. The goals of Math Mentor are to strengthen teachers' mathematics content knowledge while increasing their use of hands-on and problem solving teaching practices in order to improve the achievement of their students. After this program, participants go on to serve as methematics mentors in their own schools and districts.

The training program consists of a summer institute and sessions throughout the academic year, with a new mathematical topic every year. Participants use the manipulatives and materials that students would use as they learn both new methods and new content. During the academic year, the sessions focus on implementation of the activities used in the summer. The experience also gives teachers the opportunity to discuss and reflect on what activities worked and how to improve their practices.

Contact:
Charles P. Geer, Project Co-director
College of Education, Texas Tech University
PO Box 41071
Lubbock, TX 79409-1071
(806) 742-1997, Ext. 276 / Fax: (806) 742-2179
E-mail: c.geer@ttu.edu

PBS Mathline

This professional development resource combines instructional technologies and encourages teachers to collaborate to investigate, discuss, and improve their teaching practices. Teachers of primary, middle, and high school students gather in communities facilitated by experienced teachers to watch video lessons. These videos show classrooms that use standards-based instruction, and provide opportunities for viewers to discuss and reflect on the practices used. Lesson guides and online discussions allow teachers to participate at any time that is convenient for them, and interactions can take place within a school or across the country.

Contact:
http://www.pbs.org/learn/mathline/

Teaching Math: Annenberg/CPB Math and Science Collection

This video library is designed for use in preservice and inservice workshops, by individual teachers, in parent association meetings, and by school administrators.

The library began when the Annenberg/CPB Math and Science Project issued a call for visual examples of dynamic teaching that illustrates the curriculum content and process areas outlined in the NCTM *Curriculum and Evaluation Standards for School Mathematics* (1989). The videos provide viewers with the opportunity to observe a wide range of teacher created lessons from various curricula in diversified educational settings. Each video ends with analysis questions intended to spark discussion and reflection. Also included with the video is a guidebook consisting of individual units to accompany each lesson segment. Each unit presents an overview of the lesson and an exploration activity for teacher workshops, as well as information on the classroom and a list of ideas.

Contact:
Corporation for Public Broadcasting (CPB)
The Annenberg/CPB Math and Science Collection
Dept C-96
PO Box 2345
South Burlington, VT 05407-2345
(800) 965-7373
Fax: (802) 864-9846
http://www.learner.org/

California Mathematics Project (CMP)

The CMP provides professional development through a statewide network of 17 sites, with specific initiatives for each regional area of the state. Programs are available for teachers of grades K-12, and based on the idea that increased teacher knowledge in mathematics content and pedagogy will improve student achievement. Collaborations with community college and university faculty enhance teacher learning in both mathematics content and innovative teaching practices. The statewide network relies on a teachers-training-teachers model to reach as many teachers as possible. Activities include workshops and summer institutes with academic-year support and follow-up. More than 7,000 teachers participate in CMP activities every year.

Contact:
Nicholas Branca, Executive Director
California Mathematics Project
6475 Alvarado Road, Suite 206
San Diego, CA 92120-5006
(619) 594-5081 / Fax: (619) 594-1581
E-mail: nbranca@sunstroke.sdsu.edu

Project PRIME: Promoting Reform in Mathematics Education

PRIME is a five-year training program to enhance the mathematical knowledge and leadership skills of teachers of grades 3-8. The goal is to select teams of teachers from the middle school and feeder elementary schools. The program adopts an integrated approach to the teaching of mathematics — to blend the teaching of subject matter with the use of problem solving and technology.

Teachers participating in PRIME are provided with various support activities during the academic year including team meetings, inservices, and classroom visits by PRIME faculty and support teachers, peer teachers, and evaluation team members. During the academic year, the support teachers have a unique role as the key link between the University of Arizona Department of Mathematics and the participating schools. To facilitate the implementation of the goals of the program, the participating school districts equip the classroom of each participating teacher with a set of calculators, a microcomputer with overhead and LCD panel, selected manipulatives, and software.

Contact:
Elias Toubassi & Marta Civil, Project Directors
University of Arizona, Department of Mathematics
PO Box 210089
617 N. Santa Rita
Tucson, AZ 85721
(520) 621-6881 / Fax: (520) 621-8322
E-mail: elias@math.arizona.edu

Rational Number Project: Middle Grades Teacher Enhancement

The goal of this project is to develop teacher enhancement programs that assist teachers as they implement National

Science Foundation (NSF)-sponsored curricula. The Rational Number Project has sites across the country. At one site, Minneapolis-area teachers attend four-week summer institutes during this two-year program, and attend meetings during the academic year. During the institutes, teachers use activities that emphasize hands-on methods; they also conduct research on various topics, including gender issues and learning theory.

Follow up consists of visits from project staff during the academic year. In the first year, teachers implement specific units and activities, and during the second year they implement a new curriculum with on-site support. The project is creating a handbook to assist teachers in choosing and implementing new NSF-sponsored curricula.

Contact:
Thomas Post, Project Co-director
University of Minnesota-Twin Cities
159 Pillsbury Drive, SE
Minneapolis, MN 55455-0208
(612) 625-0069 / Fax: (612) 624-8277
E-mail: postx001@maroon.tc.umn.edu

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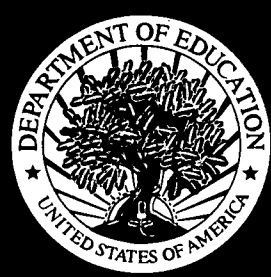

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