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ABSTRACT

The National Science Foundation (NSF) has supported a wide variety of teacher enhancement projects in order to identify and explore strategies that are effective in bringing genuine, long-term teacher change, and, ultimately, long-term systemic change in schools. In November 1994, with funding provided from NSF (Grant Number ESI-9452859), a small, informal conference was held that focused on teacher enhancement in elementary mathematics education with the goal being to organize, summarize, and discuss what is known about factors for effective teacher enhancement. A number of common principles emerged that may be used to guide development of teacher enhancement programs in K-6 mathematics education. This article summarizes these principles, with special attention given to professional development for teacher leaders. (Contains 24 references.) (Author/MVL)

4 Effective Professional Development for Teacher Leaders: Lessons Learned from K-6 Mathematics Teacher Enhancement Program

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The National Science Foundation (NSF) has supported a wide variety of teacher enhancement projects in order to identify and explore strategies that are effective in bringing genuine, long-term teacher change, and, ultimately, long-term systemic change in schools. In November 1994, with funding provided from NSF, a small, informal conference was held that focused on teacher enhancement in elementary mathematics education with the goal being to organize, summarize, and discuss what is known about factors for effective teacher enhancement. A number of common principles emerged that may be used to guide development of teacher enhancement programs in K-6 mathematics education. This article summarizes these principles, with special attention given to professional development for teacher leaders.

> *Mathematics teachers develop professionally in the same ways all other teachers do but with a specific focus of applying professional knowledge within a meaningful and relevant mathematical context for the improvement of the mathematical understanding of children and youth.* (Castle & Aichele, 1994, p. 3)

For a number of years, there has been general agreement that K–12 mathematics teaching in the United States is in critical need of major reform. In responding to this identified need, the National Science Foundation (NSF) has supported a wide variety of teacher enhancement projects in order to identify and explore strategies that are effective in bringing genuine, long-term teacher change, and, ultimately, long-term systemic change in schools. These "pilot"

or "experimental" programs have permitted NSF and the principal investigators to explore a variety of strategies for working with teachers to promote changes in the ways they teach and facilitate student learning of mathematics.

In November 1994, with funding provided from NSF[1], a small, informal conference was held that focused on teacher enhancement in elementary mathematics education. Conference attendees included recognized experts in professional development and teacher change for K–6 teacher enhancement, primarily in mathematics. They were convened in order to organize, summarize, and discuss what is known about factors of effective teacher enhancement.

Based on papers prepared for the conference and discussions during the conference, a number of common principles emerged that may be used to guide development of teacher enhancement programs in K-6 mathematics education (Friel & Bright, 1997). In this article, we present a summary of the common principles; many of these principles have emerged through the practice of professional development. Clearly, each provides the potential for rich discussion and research in order to document both "how to put it into action" and to provide the evidence and rationale for why specific practices result in changes that ultimately lead to improved mathematics instruction.

These principles may be presented visually in a way that clarifies their interrelationships (Figure 1). A critical filter for any efforts for change is beliefs about the three interrelated components of mathematics teaching: knowledge of mathematics, knowledge of mathematics pedagogy, and knowledge of students' mathematical thinking. These three components frame the heart of teaching mathematics. Professional development opportunities may focus, to varying degrees, on assisting teachers in their efforts to address these components either individually or in combination. No matter what the goals of professional development[2], in the end we are asking teachers to consider the relationships among the three areas in light of their own beliefs.

[1]National Science Foundation Grant Number ESI-9452859. Any opinions, findings, conclusions, or recommendations expressed in this article are those of the authors and do not necessarily represent the views of the National Science Foundation.

[2]Professional development in mathematics education may include: summer workshops, scheduled meetings, ongoing seminars that focus on practice, follow-up professional development days for sharing, use of action research projects, classroom visits for purposes of coaching, teacher-planning time for teams to work together, or conversations among teachers between classes.

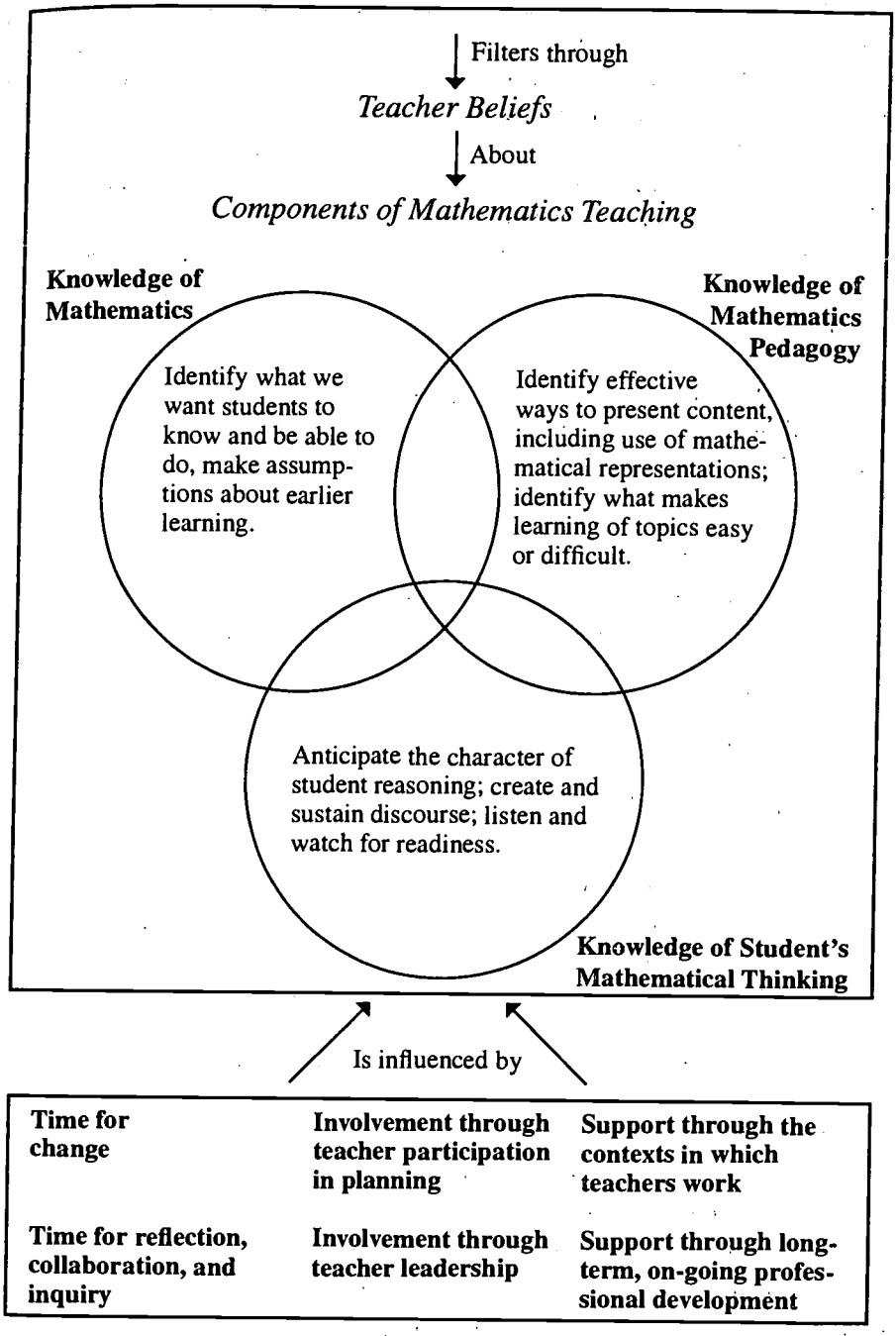

Figure 1. A Framework for Thinking about Professional Development in Mathematics Education

In addition to teacher beliefs and their interaction with the three components that frame the heart of mathematics teaching, there are a number of other factors that have an impact on effective professional development programs in mathematics education (Figure 1). These factors highlight teachers' needs for (a) time to change and to reflect, collaborate, and inquire about their practice; (b) for involvement in planning agendas for change and involvement through teacher leadership; and (c) for support gained both through the context of the school environment and through an on-going program of professional development.

Anyone who is involved in providing professional development for teachers needs a framework for their work. The framework proposed here is one example. In particular, it makes explicit issues that teacher leaders need to keep in mind as they work with their colleagues in a variety of professional development contexts.

Teacher beliefs: A critical filter

> *Most teachers and learners have well formed views on the nature of mathematics and these views have a profound influence on the way mathematics is taught and learned.* (Ernst, 1989, as cited in Laurenson, 1995, p. 3)

We know that stated beliefs may not always appear to be consistent with practice (Laurenson, 1995). Indeed, teacher beliefs about mathematics, mathematics teaching, and students' mathematical knowledge may be explicitly stated or may be implicit and not at the level of awareness on the part of the believer. Working to identify and to change teacher beliefs needs to be the first and primary work of professional development (Loucks-Horsley, 1997). However, the strategies that support changes in teachers' beliefs are not clearly defined. Recent research has indicated that when teachers experiment with their practice in teaching mathematics, they may experience changes in their beliefs (Loucks-Horsley, Hewson, Love, & Stiles, 1997).

> *It is clear that teachers' beliefs about the value of certain reformist tenets shift as a result of their tentative experimentation with practice.* (Ferrini-Mundy, 1997, p. 123)

Part of this change is motivated when teachers see evidence of student success in their classrooms during such experimentation. As teachers' conceptions of learning and mathematics change, they begin

to see their classrooms through different eyes and want to interact differently with their students. Other strategies that have the potential to impact beliefs and practice include reflecting on the content of videotapes of one's own teaching of mathematics; discussing readings that focus on topics of differences in students' learning and understanding of mathematics; or analyzing cases written about the dilemmas of teaching mathematics.

Professional Development and the Components of Mathematics Teaching

Knowledge of mathematics

The importance of subject matter knowledge in learning to teach for understanding cannot be ignored. Inservice programs need to provide opportunities for teachers not only to explore their own mathematics content knowledge, but also to help teachers learn how to learn mathematics in the context of their own teaching. One way to address this is to involve teachers first in the doing of mathematics for themselves.

> *We are now confident that doing mathematics and reflecting on it makes a major contribution to a paradigm shift for many teachers in a long-term staff development program. Shifting the focus from their teaching helps some teachers pursue their own mathematical identities. Subsequently they develop more mathematical confidence... Too often in inservice meetings teachers' own mathematics is not being enhanced because the mathematics in teacher enhancement seminars is done for the children.* (Corwin, 1997, p. 188-89)

The practice of addressing mathematics for teachers as learners is not always popular with teachers; teachers involved in doing mathematics often argue that they can't afford the time (Parker, 1997). Their preference is to have new activities for their classrooms. However, with time, teachers do come to value this process and their own mathematical empowerment.

The *Professional Standards for Teaching Mathematics* (NCTM, 1991) highlight the importance of having teachers revisit school mathematics, this time from a perspective quite different than the one they held as students.

> *Too often, it is taken for granted that teachers' knowledge of the content of school mathematics is in place by the time they complete their own K–12 learning experiences. Teachers need opportunities to revisit school mathematics topics in ways that will allow them to develop deeper understandings of the subtle ideas and relationships that are involved between and among concepts.* (NCTM, 1991, p. 134)

There are a number of ways to engage teachers in learning mathematics content, including exploring within the context of adult-relevant mathematical activities, studying the use of rich problems with students so that students' thinking is exposed, exploring adult-level tasks that focus on content that is generally relevant to the mathematics content that teachers are expected to teach, and inquiring into cases of classroom practice that provoke the need for a deeper understanding of mathematical thinking that has occurred.

Knowledge of mathematics pedagogy

It often is noted that teachers teach the way they are taught; this should not be a surprise, given the fact that we build our world views from within the context of personal experience. Such a perspective justifies the maxim that professional development experiences must model appropriate pedagogy.

> *Mathematics and mathematics education instruction should enable all learners to experience mathematics as a dynamic engagement in solving problems. These experiences should be designed deliberately to help teachers rethink their conceptions of what mathematics is, what a mathematics class is like, and how mathematics is learned.* (NCTM, 1991, p. 128)

Teacher educators and staff developers need to model the approaches which they are promoting. This becomes more problematic as the directions for teaching shift to a constructivist view of learning. What does it mean to provide a constructivist environment in which to support teachers' learning as it relates to mathematics education?

> *It is increasingly evident that tenets of constructivism apply to adult learners. Learning is a meaning-making process which is personally constructed and impacted by experience, context, and the environment. Teachers need to continuously*

> *experience learning through problem solving and inquiry before they can own the process.* (Gregg, 1997, p. 217)
>
> *Just as mathematics instruction must be organized to facilitate construction of mathematical concepts, so should in-service instruction facilitate construction of a new pedagogical theory and practice.* (Schifter, Bastable, & Russell, 1997, p. 256)

Constructivist pedagogy extends well beyond the workshop. When teachers share personal experiences and particular struggles and triumphs, they acknowledge that this hard work is an important part of the process of change. This helps teachers see that the process of learning something new has ups and downs for everyone—themselves, their colleagues, and their students. Summer institutes and Inquiry Groups where teachers work collegially can provide a context in which they can learn to listen to another person's mathematical thinking and ask the questions that help one another stretch their thinking (Nelson, 1997).

Knowledge of students' mathematical thinking

Teachers' knowledge of content and pedagogy interacts with their knowledge of children. Knowledge of children and their mathematics is crucial to teaching mathematics for understanding. The changes in mathematics instruction proposed by the *Standards* (NCTM, 1989, 1991, 1995) require the development of professional and school cultures that support ongoing inquiry into how students' mathematical thinking develops.

In Cognitively Guided Instruction (CGI), Fennema and others have focused on how learning about children's thinking in whole-number arithmetic influences primary grades teachers' instruction, beliefs, and the learning of their children across all mathematics.

> *Knowledge of their own children's thinking enables teachers to make instructional decisions so that children's learning of mathematics improves.* (Fennema, Carpenter, & Franke, 1997, p. 195)

The structure of the professional development experiences in CGI engages teachers in doing activities which make it possible for them to consider a research-based model in relationship to children. A key component to this project is viewing videotapes of children solving problems and identifying relationships between the solution strategies

and the problem types. Teachers are challenged to use children's solution strategies to predict how children will solve other problems. Eventually, teachers interact with their own students in a similar manner in order to make visible their students' thinking in ways that can be used to direct instruction.

Emerging from the work of this project and other similar projects (e.g., Campbell & Robles, 1997) is the expectation that teachers will reflect on the needs of their children and work with others to determine the activities, problems, or resources they need to use. Three possible approaches on how to do this surface.

> *One scheme is to make time available to examine and discuss examples of commercial materials that address mathematical topics appropriate for children. The second venue is to offer examples of activities or tasks, but always with another purpose in mind. For example, a problem may be offered as an illustration of how one could facilitate a child's re-examination of a mathematical construct. In another setting, a task may be presented, and the teachers may be asked to write questions that they could ask to determine what mathemaical ideas the children were constructing as they completed the task. A third approach is to follow an adult-level mathematics session with the challenge to the teachers to define a task that would address that same mathematical topic at a level appropriate for their students.* (Campbell & Robles, 1997, p. 184)

There also is value in structuring interview sessions with small groups of children (Gregg, 1997). While one teacher interviews students to probe their thinking about a specific mathematical idea, a second teacher observes and records responses. As the teachers learn about the conceptions children hold and how children think, they increasingly are willing to restructure learning experiences in their own classrooms, engage in dialogue about the results, and continue to work to improve instructional practice. At the same time, they may well deepen their own understanding of mathematics.

One way to connect the three components of mathematics teaching

Decisions about mathematical content emphasis, pedagogical strategies, and so on may be quite dependent on the nature of the curriculum being used. There are a number of possible critical focal

points (e.g., curriculum, pedagogy, assessment) that could serve to "ramp up" our capacity for professional development. Cozzens and Robinson (1994) make an excellent case for the use of curriculum. Indeed, the choice of curriculum may well set the context for what is valued as mathematics and mathematics pedagogy.

Curriculum can serve as a tool for professional development (Russell, 1997). While there are several views of what constitutes a mathematics curriculum, one of the more productive views is that the best mathematics teaching environment is a partnership between teacher and curriculum.

> *The link between curriculum and teacher decision-making is a focus on mathematical reasoning. Neither curriculum nor teacher can fully anticipate the complex and idiosyncratic nature of the mathematical thinking that might go on among thirty students in a single classroom during any one mathematics class. However, both teacher and curriculum contribute to a repertoire of knowledge about student thinking that leads to better mathematics teaching and learning.* (Russell, 1997, p. 248-249)

The best use of good curriculum materials may well be in the context of a long-term staff development program in which teachers engage in ongoing reflections about their students' mathematical thinking and about their own continued work with their colleagues around mathematics content. Curricular materials can be a vehicle for ongoing teacher development that may be used to help deepen teachers' knowledge of mathematics content, of children's mathematical thinking, and of new pedagogical approaches.

Acquarelli and Mumme (1996) emphasize that professional development needs to be grounded in classroom practice. The ability to tie professional discussions and examination to what's going on in classrooms gives teachers opportunities to grapple with what reform is all about. Focusing the talk on curricular units appears to be particularly helpful to the process. Curriculum not only allows teachers to be exposed to big mathematical ideas in coherent, practical-sized chunks, it also becomes a tool for investigating problems of practice.

Factors that Influence Professional Development in Mathematics Education

Time for change and for reflection, collaboration, and inquiry

Learning to create the kinds of teaching envisioned by mathematics reform takes a *long time* and is hard (Ball, 1997). It is possible to characterize a developmental perspective within which to frame change as a process through the Concerns-Based Adoption Model for describing teacher change (e.g., Hall & Hord, 1987).

> *People undergoing change evolve in the kinds of questions they ask and in their use of the change. In general, early questions are more self-oriented (what is it? how will it affect me?); when these questions are resolved, questions emerge that are more task-oriented (how do I do it? how can I use these materials efficiently? how can I organize myself? why is it taking so much time?). Finally, when self and task concerns are largely resolved, the individual can focus on impact: is this change working for my students? Is there something that will work even better?* (Loucks-Horsley, 1997, p. 135)

Such a developmental perspective has implications for professional development in mathematics education (Loucks-Horsley, 1997; Friel & Gann, 1993). Clearly, it is important (a) to attend to where people are and to address the questions they are asking when they are asking them, (b) to pay attention to implementation over several years because of the transitions people need to make between resolving earlier concerns and moving forward with newer concerns, and (c) to create realistic expectations in the system for change.

Change is a process not an event. Such a view suggests that as teachers change, their visions of the teaching and learning also change. Implicit within this context is the need to address ways for teachers to collaborate and/or reflect together about teaching and learning mathematics in order to facilitate the process of change. A key component to facilitating such collaboration and reflection is having the *time* to plan for teaching and learning. The need for adequate time to teach and time to learn (plan, collaborate, reflect) appears at the top of most teachers' lists of roadblocks to carrying out proposed reforms in mathematics education.

The majority of teachers carry out their practice in isolation from one another; the often-expressed need for collaboration points to the issue of isolation. Working collaboratively can promote and support teachers in their inquiry into their practice of mathematics teaching and their efforts to change their practice and, simultaneously, to reflect on the impact of changes made. The kind of teaching that is now proposed with respect to mathematics requires a greater investment on the part of the teacher in the instructional responsibility and also entails a greater need for collegial cooperation (Schifter, 1997). There are a variety of strategies that may be used for promoting reflection, collaboration, and inquiry, a number of which have been noted earlier in this article.

Teachers' involvement in their own professional development and teachers' involvement through teacher leadership activities.

It is important that teachers have a central role in making choices and planning agendas with respect to their professional development in mathematics education. While it is evident that teacher development may be especially productive when the teachers are in charge of the agenda, such a stance raises concerns that revolve around what might be characterized as "the blind leading the blind." What is the role for teachers (and other school personnel) and for "experts" in making decisions about the nature and content of professional development?

One way to address this need is to help teachers develop a preliminary understanding of new directions in mathematics education before initial planning efforts are implemented. In one project (Bright, Miller, Nesbit, & Wallace, 1997),"visioning" sessions were conducted prior to the teachers' carrying out needs assessments of the mathematics programs at their respective schools. The intent was to expose teachers to such change efforts as those proposed by the NCTM *Standards* (NCTM, 1989, 1991) and to provide them with opportunities to engage in one or more situations in which they experienced mathematics in a way that modeled the directions detailed in these *Standards*. The purpose was to help teachers broaden their views about what is good mathematics instruction so that they could better assess both their programs and their needs in light of this vision. Once they had participated in the visioning sessions, teacher leaders spent time assessing their needs at the school level with respect to mathematics education and, using their needs assessments, developing

school improvement plans. The school improvement plans became the basis for planning the content of the summer workshops.

Still others argue that there is an important place for outside experts in helping to initiate and lead change efforts.

> *Ongoing involvement of nationally recognized experts strengthens and enriches every aspect of reform projects. Consultants ... have the capacity to be objective about local conditions which impact the success of reform. Outside change agents are free to challenge ideas and practices and offer constructive suggestions from a national perspective.* (Gregg, 1997, p. 219)

It may well be true that such change agents, working with district decision makers and removed from internal politics, may be able to more easily challenge existing structures and practices.

In part because of the limited capacity in terms of people available to support teachers in working toward reforms in mathematics education, and in part because of the importance of making changes that are congruent within a school culture, the use of specialists of many sorts seems to be emerging as a key to successful efforts in schools (Ferrini-Mundy, 1997). Specialists (e.g., teacher leaders, mentor teachers) may be involved in spreading ideas, facilitating communications among teachers, initiating and planning staff development, and addressing political problems with administrators and community members.

Teacher leaders can play two roles in their schools. First, they can model quality mathematics instruction in their own classrooms. Part of the professional development that helped them become leaders should have helped them understand not only characteristics of quality mathematics instruction but also ways of implementing that kind of instruction. By inviting others to watch them teach, teacher leaders can provide images of what quality instruction looks like. Second, teacher leaders can encourage their peers to reflect on their own instruction in order to identify its strengths and weaknesses. Teacher leaders can explain model processes that are helpful in making such reflections, and they can also act as "sounding boards" when their peers try to do that reflecting.

In developing the capacity for teacher leadership in mathematics education, one of the dilemmas is how to identify those who will be leaders. A caution may be raised about identifying teacher leadership

candidates too early; teacher leaders often "emerge" as part of a process of professional development. Those who do emerge are teachers that often have credibility with their peers and also demonstrate that they are willing to take risks and push for deep-level mathematics restructuring in their own classrooms. The ability to tap into their own classroom experiences provide leaders with "personal memory tapes" of the practical, as well as the pedagogical, issues related to implementation.

Leadership projects often highlight the importance of teacher teams. Parker (1997) identifies two major reasons why change agents should work in teams. The first addresses the concerns of expertise. Teacher teams that are cross-grade level permit leaders to articulate connections between grade levels and, for that matter, between school levels, assuring that consistent and compatible practices are being promoted overall. "Second, restructuring efforts that result in classrooms, schools, and districts aligned with the NCTM Standards are long-term, involve many unanticipated surprises, and can often be messy, uncomfortable, and frustrating for both participants and change agents" (Parker, 1997, p. 244). Teachers, as change agents, will benefit from the support that comes from working in teams as they work to understand and communicate the complex dynamics involved in change efforts of this magnitude.

Support within the context of the school and through on-going professional development.

Teachers work within both the school/school district and the community. This context includes not only the space and resources provided by the school district but also the students, parents, administrators, testing practices and policies, and district and state curricular objectives and guidelines. Context may be viewed as a "systems concern," that is, the success of professional development depends on simultaneous attention to changing the systems within which teachers work (Loucks-Horsley, 1997). If change is to happen, it is the systems in which teachers live and work that must be aligned and strengthened.

Not only does a school function within a community, it also is an involved and informed community itself. Large-scale teacher change in mathematics education occurs by school, not by individual(s). Being a member of the school community matters, and attention to the culture of the school is an important component of change. There

is no doubt that "empowered" teachers of mathematics returning to "unempowered" environments often experience set backs and defeats. Teacher learning is both an individual and collective community activity, and lack of support and isolation make growth and change very difficult.

Teacher leaders can often act as bridges between individual teachers and the school community. They are typically perceived by the other teachers as "one of the," since they are, after all, part of the instructional staff. At the same time, in their leadership roles, they have contacts with school administrators and outside experts. Teacher leaders can view the school's environment from both the "top down" and the "bottom up."

The importance of both principal and parent involvement with respect to the changes being made cannot be over-emphasized. The principal's role should be that of instructional leader.

> *Active participation is necessary if principals are to be knowledgeable of mathematics reform goals, able to distinguish between classroom practices consistent with and inconsistent with those goals, understanding of the change process, prepared to support teachers' risk taking and growth through periods of confusion and discouragement, and able to effectively communicate the necessity and goals of mathematics reform efforts to parents and to teachers.* (Parker, 1997, p. 239)

Attention to community involvement may range from notes home and parents' nights to formal committees involving parents in making decisions about the goals of a mathematics program (Ferrini-Mundy, 1997). Better articulation of what needs to be done and how to do it in the context of systemic attention to school and community involvement is essential in supporting successful professional development efforts.

In addition to the support of school and community, the role of continued professional development in the form of long-term support cannot be over-emphasized (Ball, 1997; Loucks-Horsley, 1997). There are a variety of ways to plan for such support, including, but not limited to, helping teachers to reflect on their practice, building networks through which teachers can learn from each other, maintaining the focus of a staff development program for a sufficient duration so that teachers can internalize the change, helping teachers overcome

less-than-optimal conditions that may work against their continued development once they return to their school, facilitating discussion and communication among teachers, providing time for someone to visit and support what is happening in the school, and providing a sounding board for issues and concerns. On-site support appears to be a critical aspect. This may be provided in a variety of ways, including by someone in the building such as a teacher leader or some other designated person or group, a team partner who might be at another school, electronic teaming, and so on. As Bush (1997) notes, a successful teacher enhancement project should use professional development models which include mentoring, peer coaching, team teaching, and reflection.

There continues to be a lack of clarity, however, about what constitutes "effective support." While many projects engage in long-term support, it has been difficult to capture the essence of this support from written descriptions. For example, what does a support person do when making classroom visits? Is there some developmental process that provides insights into when the use of such strategies as demonstration teaching or coaching may be appropriate? How do we better understand the dynamics of informal support as provided by teacher leaders? The list of questions goes on and on.

Conclusion

It seems that the events that begin a project need to meld into the building of a community that provides support for changes in mathematics teaching in a variety of ways. Part of the building of a community involves making explicit the beliefs about mathematics teaching and learning of everyone in the community. Visions of possibility with respect to the components of mathematics teaching may be created in inservice courses or institutes by focusing on knowledge of mathematics, pedagogy, and students' mathematical thinking as a framework. But the realities of implementation happen in teachers' classrooms with their own students in their own schools. As teachers work to make changes in practice, they encounter innumerable issues and concerns that could not be predicted, much less addressed, by earlier inservice work. The debriefing of these issues and concerns can be tied to discussion of changing beliefs and discussion of the three components of mathematics teaching. A community that supports the visions of change is necessary if teachers are to address the questions and challenges that arise and

be encouraged in their continued efforts to make the changes in mathematics teaching and learning that are needed.

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