Principles and Standards for School Mathematics and Teacher Education: Preparing and Empowering Teachers

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Teachers and teacher educators play a critical role in the improvement of mathematics education. Recommendations for appropriate teacher support can be gained from examining the Teaching Principle in the document, Principles and Standards for School Mathematics *(NCTM, 2000), as well as earlier recommendations from the* Professional Standards for Teaching Mathematics *(NCTM, 1991). This paper discusses implications of the recommendations for preservice teacher preparation, the continuing professional development of teachers, and mathematics teacher certification policy.*

> Students learn mathematics through the experiences that teachers provide. Thus, students' understanding of mathematics, their ability to use it to solve problems, and their confidence in, and disposition toward, mathematics are all shaped by the teaching they encounter in school. The improvement of mathematics for all students requires effective mathematics teaching in all classrooms (National Council of Teachers of Mathematics [NCTM], 2000, p. 16-17).

This quote from NCTM's *Principles and Standards for School Mathematics* (2000) describes the intimate relationship between student learning and mathematics teaching. Recognizing that teachers play a critical role in the improvement of mathematics education leads to questions about what types of support and experiences are necessary for teachers to carry out their role more effectively. Insights into and implications for appropriate teacher support can be gained from examining the Teaching Principle in the document, *Principles and Standards for School Mathematics,* as well as earlier recommendations from the *Professional Standards for Teaching Mathematics* (NCTM,1991), various other national reports and teacher certification policies, and recent research and professional development projects. All of these documents and projects support the concept of teaching as a complex endeavor with multiple approaches.

Successful teaching depends on teachers' ability to make decisions based on their knowledge of the mathematics, the curriculum expectations, the classroom/school environment, and the needs of the students. "Effective mathematics teaching requires that teachers understand what students know and need to learn and then challenging and supporting them to learn it well (NCTM, 2000, p. 16)." How does this happen? Teachers gain the ability to make effective and appropriate decisions through their experiences in preservice and in-service professional development programs. This article discusses implications of the *Principles and Standards* and related activities for teacher education programs. The discussion begins with a brief description of the Teaching Principle and its relationship to earlier recommendations. This discussion will be followed by implications for the recommendations in the areas of preservice teacher preparation, the continuing professional development of teachers, and mathematics teacher certification policy.

The Teaching Principle and Teacher Education

The view of teaching set forth in the Teaching Principle describe teaching as a "complex endeavor [with] no easy recipes for helping all students learn or for helping all teachers become effective" (NCTM, 2000, p.17). As with the subject area of mathematics, no one way to approach mathematics teaching will work with every student in all situations. From this perspective, a teacher becomes a problem solver, making decisions based on knowledge and experience, continually and actively questioning, observing, and reflecting. In the Teaching Principle three major tenets for effective teaching were outlined, based on the literature in this area:

- Effective teaching requires knowing and understanding mathematics, students as learners, and pedagogical strategies.
- Effective teaching requires a challenging and supportive classroom learning environment.

- Effective teaching requires continually seeking improvement. (NCTM, 2000, p. 17-19)

These tenets have implications for both preservice teacher preparation and professional development programs for teachers. At the preservice level the recommendations represent a change from a major emphasis, particularly at the secondary level, on mathematical content knowledge, with a minor emphasis on the methods of teaching to the recognition that mathematics content preparation, by itself, is not sufficient. "Teachers need to know and use 'mathematics for teaching' that combines mathematical knowledge and pedagogical knowledge" (NCTM, 2000, p. 370). Given this view, interesting questions have developed about what type of mathematical content knowledge is appropriate and necessary for individuals preparing to be teachers. In addition to discussions about what type of mathematical experiences are appropriate for the preparation of teachers, there is growing recognition that preservice teacher education is only a beginning and, as such, provides individuals with only a small part of what they will need to know during their career as mathematics teachers. As a result, teacher development is increasingly being viewed as a career-long process, based on the assumption that no matter how well prepared people are they

> ...will need sustained, ongoing professional development in order to offer students a high-quality mathematics education. They [teachers] must continue to learn new or additional mathematics content, study how students learn mathematics, analyze issues in teaching mathematics, and use new materials and technology (NCTM, 2000, p. 370).

This vision suggests that preservice teacher preparation programs need to be structured so that prospective teachers begin to view themselves as lifelong learners, committed to a career-long process of professional growth, essential for continued effectiveness in a rapidly changing profession. The education system in most schools and communities will need to be radically restructured to accommodate such a system of continual professional development; a system that provides opportunities for teachers to deepen their content and pedagogical knowledge and to analyze and reflect while involved in the practice of teaching. Models of preparation and professional development activities consistent with this vision are being developed, implemented, and discussed within the mathematics education community. Some examples will be presented later in this discussion. First, to gain a deeper understanding of the vision outlined in the Teaching Principle and how it reflects current thinking in the mathematics education community, this article will describe ways the Teaching Principle relates to and builds on earlier recommendations, such as those outlined in NCTM's 1991 document, *Professional Standards for Teaching Mathematics*.

The 1991 *Professional Standards for Teaching Mathematics* set forth six standards for teachers of mathematics, describing aspects of mathematics teaching practice that support the teaching and learning described in the earlier *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989). The *Professional Standards'* focus on "worthwhile mathematical tasks" and "discourse" had particularly strong implications for teachers' efforts to implement the *Curriculum and Evaluation Standards*. In addition, anecdotal evidence indicates that these two notions appealed strongly to those working in teacher education.

The Teaching Principle, as well as other aspects of the *Principles and Standards*, built from these important ideas and attempted to convey in detail the expectations teachers must meet in the complex tasks of teaching. The emphasis on mathematical tasks was elaborated in the 2000 document, in an attempt to counter what might have been shallow interpretations of the 1991 recommendations. The Teaching Principle clarified the 1991 recommendation by stating that

> the tasks may be connected to the real-world experiences of students, or they may arise in contexts that are purely mathematical. Regardless of the content, worthwhile tasks should be intriguing, with a level of challenge that invites speculation and hard work (NCTM, 2000, pp. 18–19).

The notion from the 2000 document that mathematical tasks should be about "important mathematical ideas" built explicitly on the 1991 discussion about the mathematical content of the task. And the Curriculum Principle reminds teachers that tasks alone are not enough: "A curriculum is more than a collection of activities; it must be coherent, focused on important mathematics, and well articulated across the grades" (NCTM, 2000, p. 14). Similarly, the ideas about discourse introduced in the *Professional Standards*, which have appealed to teachers and teacher educators, clearly underlie the Teaching Principle, as is visible in the description of a challenging and supportive classroom learning environment. In the Communication Standard, a variety of types of discourse were described (presenting methods for solving problems, justifying reasoning, or formulating questions). The ideas introduced in the 1991 standards, and elaborated and revisited in the 2000 standards, portrayed the work of

mathematics teaching as complex and demanding, and the issues for teachers, and those who educate them, became all the more challenging. A discussion of the implications of the *Principles and Standards* for teacher educators, leaders of professional development activities, administrators, and policy makers follows.

Implications for Preservice Mathematical Preparation of Teachers

Teacher education programs in mathematics have changed over the years. In the early to mid-1900s, graduates of 2-year normal schools formed the bulk of the teacher cadre in this country. These state and regional normal schools grew to 4-year state colleges in the mid-1900s. With the move to 4-year degree programs, more mathematics was required of prospective teachers. Teachers majored in either elementary (K-8) or secondary (9-12) education. Their background included a core of mathematics courses if they prepared in secondary mathematics and one to two specialty courses (e.g., mathematics for elementary teachers), if they prepared for elementary teaching. During the normal and state college years of massive teacher training, early childhood and special education programs were only beginning to emerge.

A recent exploratory study of teacher preparation programs in the United States by Graham, Li, and Curran Buck (2000) revealed that the programs of today do not differ substantially from those in existence in the mid-1900s. For prospective high school mathematics teachers, the completion of a full major in mathematics, or its equivalent, is typical. At present, only 17 states offer certification for middle school mathematics teachers. Program requirements leading to mathematics certification at the middle school level vary from institution to institution but typically represent a combination of the high school and elementary programs. Elementary education certification programs typically require between 6 and 12 credits of mathematics. Early childhood and special education certification programs vary in their content or subject area requirements. Some states have no mathematics requirements for special education teachers. Early childhood education programs may require as little as one course or three credits in mathematics for prospective preK-3 teachers. Given this relative paucity of mathematics content courses in preparation programs for early childhood, elementary, and special education teachers, it is easy to suggest that the "problem" with the teaching and learning of mathematics in such classrooms is rooted in the limited content background of the teachers. However, as indicated, content is only a partial response to this complex issue.

In addition to the content requirements, prospective teachers typically complete a course and/or related experiences dedicated to the teaching of mathematics. This typically three to four credit methods course has far-reaching responsibilities in providing prospective teachers with background knowledge and experiences in topics ranging from curriculum awareness to the use of varied assessments and from using manipulative materials to using technology. In addition, the course focuses on planning and implementing instruction. Graham et al., (2000) found that at most institutions mathematics content and methods courses have two different homes; content courses are typically taught in the mathematics department, and methods courses are typically taught by faculty in the education department. Such a segregation

> would seem to work against any effort to establish a view of mathematics teacher preparation as a coherent process. In addition, the division may foster a perspective that methods are unrelated to content or that content is more important than methods. (Graham et al., 2000, p. 20)

Ball and Bass (2000) recognized this as an age-old debate and state that this "splintering in preparation leaves to individual teachers the challenge of integrating subject matter knowledge and pedagogy in the context of their work"(p. 86). A related issue is the teachers of such courses. Preliminary work (Fennell, 2001) suggests that in many colleges and universities the single preservice level course dedicated to mathematics pedagogy is taught by an adjunct faculty member, often a precollege teacher offering the course one night a week after teaching a full day.

Despite the surface appearance that little has changed in mathematics teacher preparation programs since the mid-1900s, the recent recommendations *(Professional Standards for Teaching Mathematics*, NCTM, 1991, *Principles and Standards for School Mathematics*, NCTM, 2000, and *Mathematical Preparation of Teachers*, Conference Board of the Mathematical Sciences (CBMS, 2001) have fueled discussion and subsequent research and curriculum development initiatives that have the potential to change the future practice of mathematics teacher preparation. In particular, there is growing consensus in the mathematics education community that prospective teachers need to acquire several different types of knowledge – content knowledge, pedagogical knowledge, and pedagogical-content knowledge (Fennema & Franke, 1992). What does this mean?

What questions does it raise for mathematics teacher preparation and professional development programs?

First, in terms of *content knowledge*, few would argue with the premise that prospective teachers must know mathematics and know it well, certainly beyond the level of the children they may teach. In some ways the issue of the mathematics content background for teachers is simultaneously simple and complex: Simple in that completing more mathematics coursework should logically increase the prospective teacher's content background; complex in that merely taking courses or requiring courses is not enough. "Research has shown that the number of mathematics courses taken by teachers does not correlate significantly with their effectiveness as measured by student learning (National Research Council (NRC), 2001)." The question remains, what types of mathematical content experiences are most appropriate for mathematics teacher preparation and continuing professional development?

"*Pedagogical-content knowledge* is a special form of knowledge that bundles mathematical knowledge with knowledge of the learner, learning, and pedagogy" (Ball & Bass, 2000, p. 88). The term, first introduced by Shulman and his colleagues in 1986, is based on the premise that in addition to content and pedagogical knowledge "teachers needed to know things like what topics children find interesting or difficult or the representations most useful for teaching a specific content idea" (Ball & Bass, 2000, p. 87). The challenge for teacher education is to forge this close relationship between the prospective teacher's deep understanding of mathematics, the mathematics instructional needs of children, and appropriate strategies for teaching. This is truly the most significant challenge in the preparation of the preservice teacher. School mathematics looks different than the mathematics the prospective teacher learns in a college classroom.

Pedagogical knowledge experiences in most programs begin with the methods course or courses that are the singular responsibility of mathematics educators. But this is just the beginning. Pedagogical knowledge is shaped through experiences with children, beginning with classroom observation and practicum experiences and continuing with significant internship experiences. A range of such experiences helps beginning teachers understand how students learn, determine what interests them mathematically, and frame the curricular issues that are important at various grade and instructional levels. Questions remain, however, in terms of the appropriate balance between content and methods; the role of field experiences in a teacher's development; and the types of field experiences most appropriate or most effective.

As teachers gain experience in relating mathematics to pedagogy, they will be able to identify and understand the big ideas confronting their students and provide engaging instructional opportunities that will meet these needs. They will also learn that big ideas vary by grade and even schools within the same school district. Ma (1999) suggested that teachers need to have a profound understanding of fundamental mathematics. Such a level of understanding is built upon content, pedagogy, and pedagogical-content knowledge.

Reaching consensus on the types of knowledge that research suggests are central to effective teaching is only the first step in determining what type of experiences should be included in effective mathematics teacher preparation programs. In particular, there is a growing body of evidence supporting the notion that "it is not what mathematics teachers know, but how they know it and what they are able to mobilize mathematically in the course of teaching" (Ball & Bass, 2000, p. 95) that is critical. Ball and Bass referred to this as "pedagogically functional mathematical knowledge," and their work is making a strong case that this type of knowledge is central to effective teaching. To explore the development of this type of knowledge, Ball and Bass are conducting a mathematical analysis of teaching practice. They suggest that there are at least three critical questions that need to be examined: (a) What mathematics is entailed by teaching? (b) What makes mathematical knowledge usable for teaching? and (c) How might teachers develop usable mathematical understanding? Insights gained from this and related work can provide information about how preparation programs should be structured to enable prospective teachers to develop pedagogically usable mathematics knowledge of this type.

Recent recommendations from the CBMS (2001) for the mathematical preparation of teachers attempted to go beyond listing content topics or courses by stressing "the need for knowledge about mathematical connections, communication, modeling, or use of technology" (NRC, 2001, p. 1). In practice, these recommendations will typically be carried out by program requirements of a particular course or courses. However, alternative models are being explored that are designed to provide prospective teachers with experiences going beyond a specific course or content topic. These models also ask them to make connections between undergraduate-level mathematics and the mathematics they may be teaching and to reflect on the process of teaching while engaged in the learning of the mathematics. *Making Mathematical Connections in Programs for Prospective Teachers* (Graham &

Portnoy, 1999) is an National Science Foundation-funded project focused on developing curriculum modules for use in upper-level undergraduate mathematics courses. These modules will provide prospective secondary school mathematics teachers an opportunity to make two types of connections — between high school mathematics and abstract mathematics and between different areas of mathematics, primarily algebra and geometry.

An important aspect of the project is the incorporation of a set of school-based field experiences into the module. These field experiences involve the analysis of high school curriculum tasks and the development and implementation of a lesson within the context of the undergraduate mathematics course. Projects with a similar goal of providing the opportunity for the prospective teacher to make explicit connections between the mathematics in the undergraduate curriculum and school mathematics are being developed at other institutions, e.g. Boston University (Greenes, 1999) and University of California at Berkeley (Usiskin, Peressini, Marchisotto & Stanley, in preparation). The evaluation and research components of projects such as these will provide useful information on how prospective teachers develop new content and pedagogical knowledge while engaging in the process of teaching and learning mathematics. Such work will provide important guidance to those teaching mathematics content and methods courses at the preservice level.

Implications for Continual Professional Development

The role of professional development is critical in the support and retention of mathematics teachers at every level. The beginning teacher is essentially an apprentice, one who needs time, support, and additional training to learn a complex craft. Even the most well-prepared preservice teachers enter a school culture foreign to them. Beginning teachers spend a lot of time and energy becoming acquainted with issues and obstacles often having little to do with the teaching and learning of mathematics. Professional development is the continuing link, in fact, lifeline, between their preservice preparation and their day-to-day work as practicing teachers. More and more teachers, and perhaps especially mathematics teachers, are leaving the profession with five or fewer years of experience. Is the lack of consistent, appropriate mentoring and professional development the cause of such departures? Probably not, but developing such programs may be part of the solution.

Similar to the students they teach, every teacher in every school has a set of individual needs, and there is no one professional development design that will work for all. However, there are common issues or needs in professional development. These needs include but are not limited to additional experiences with new and advanced mathematics content, keeping abreast of changes in mathematics curriculum and pedagogy, and exploring issues related to working with an increasingly diverse student population. For example, it makes sense that as mathematics curricula provide more challenging mathematics content for students, their teachers will have to learn more challenging content and ways to teach it (Loucks-Horsley, Hewson, Love, & Stiles, 1998). What are recent developments in the area of professional development, and what are the characteristics of successful programs?

Until recently, the typical model for many teachers and school districts was to invest in the "one-shot wonder" approach to professional development. This strategy involves bringing in an outside expert for the elixir needed to help motivate or enlighten teachers with regard to important mathematics content or pedagogy. The mathematics education community is realizing, however, that this approach never worked beyond its initial appeal, which was to captivate and motivate. While not a bad idea, this approach is lacking in consistency and ongoing, long-term support. There is a growing consensus that the work of the teacher needs to be reconfigured to foster regularly scheduled professional development at the building level. Teachers need time to reflect on the mathematics content and pedagogy that best suits their students. Moreover, they should be afforded opportunities to collaborate with colleagues as part of their professional development in order to pool knowledge, evaluate pedagogy, and compare student progress (Stigler & Hiebert, 1999).

Recent work in the creation of professional development materials, particularly at the K-8 level, has provided opportunities for teachers to review the work of other teachers and discuss the content, pedagogy, and student learning in the context of classroom vignettes or cases. *Developing Mathematical Ideas* (Schifter, Bastable, Russell, 1999), *Cases of Mathematics Instruction to Enhance Teaching* (Smith, Silver, Stein, Henningsen, & Boston, 2000) and *Multimedia Case Studies for Teacher Development* (Bowers, Doerr, Masingila, & McClain, 1999) all offer teachers the opportunities to read, view, think, and reflect about mathematics, pedagogy, and student thinking. These materials, largely centered around cases, presents mathematics in a school and class-based context offering

precisely the opportunities for professional development suggested earlier. In addition, these materials permit varied points of access and entry into issues related to mathematics content and pedagogy. Teachers involved in such projects say that these resources allow them to focus on an issue, be it content, pedagogy, or student work, to think deeply about it, and to engage in discussion that may influence their own mathematics learning and teaching.

Professional development regularly and often is the key to implementing and sustaining change. However, the extent to which a program is successful is dependent on the extent to which professional development is valued – or not. It must be valued as school districts frame budgets and as school boards approve them. Importantly, such opportunities must be supported, in fact, championed at the building level. Principals are key players, as they support and, in some cases, implement professional development programs. Teachers also need to recognize the important role of professional development in supporting their work. Finally, more work is needed to demonstrate how and when professional development has made a difference — made a difference in understanding mathematics, in supporting and retaining teachers, in implementing instruction, and/or in student achievement.

Implications for Teacher Certification and Policy

Research is confirming what common sense has suggested for quite some time: A skilled and knowledgeable teacher can make an enormous difference in how well students learn (Public Agenda, 2000). This is perhaps especially true as preservice and in-service teachers invest in standards-based instruction. Darling-Hammond (1994) has noted that the strongest predictor of how well a state's students performed on national assessments correlated with the percentage of teachers who were fully certified and had majored in the content areas they taught (Public Agenda, 2000). Yet another study indicated that low-achieving students assigned to effective teachers gained approximately 53 percentile points on standardized tests during a school year, while those assigned to the least effective teachers gained only 14 percentile points (Sanders & Rivers, 1996). Knowledge of how to teach is as important as knowledge of what to teach. Effective teachers have the ability to organize the mathematics so that fundamental ideas form an integrated whole. Teachers also need to be able to adjust and take advantage of opportunities to move lessons in unanticipated directions (NCTM, 2000). Thus, mathematics teaching is dependent upon appropriate professional training and certification, as well as ongoing professional development.

National recommendations, the National Board Certification initiative (which is endorsed by many states and local school districts), and standards for school mathematics and teacher preparation, as well as subsequent changes in the precollege curriculum, have forced an examination and change in state and national initial and continuing certification/licensure requirements. These requirements are based on the premise that every student should have teachers who are trained thoroughly in both content and pedagogy and who have proper credentials in the courses they are teaching (Maryland State Department of Education (MSDE), 1999). In addition, these teachers should be expected to be active participants in professional development activities that continually expand their knowledge and hone their skills. Several trends are evident from the national (National Council for Accreditation of Teacher Education (NCATE), 2001) and state level requirements in mathematics teacher development: a call for increased content preparation, particularly at the elementary and middle school levels, a call for content preparation closely aligned with the mathematics that will be taught, a call for more performance-based standards and assessment of teachers, and a call for programs beyond initial certification that speak to the need for the continuing development of teachers.

Students preparing to teach in nationally accredited teacher education programs are required to develop the mathematics content background and skills suggested by professional organizations in the field. These organizations include

- National Association for the Education of Young Children (NAEYC) - Early Childhood Education
- Association for Childhood Education International (ACEI) - Elementary Education
- National Council of Teachers of Mathematics (NCTM) - Mathematics Education, K-12
- Council for Exceptional Children (CEC) - Special Education.

In contrast to these guidelines from professional organizations, CBMS (2001), a consortium of 16 mathematics organizations, has completed a report on the content background of mathematics teachers, offering very specific recommendations for the mathematics content that teacher candidates should know and understand. This report recommended content requirements for prospective elementary, middle, and high school teachers. In addition, the CBMS report called for mathematics specialists at Grade 4 and above supporting NCTM's recommendation that the use of

mathematics specialists at the elementary school level is an option well worth pursuing (NCTM, 2000). The *Principles and Standards* (NCTM, 2000) noted how mathematical content develops on trajectories related to learner development. Teachers need to know how the roots of mathematically sophisticated content areas develop in the early grades (e.g. algebra, reasoning and proof, etc.) and are extended through the upper elementary years and on into middle school. They need a deep, rich understanding of the mathematics content and pedagogy. Such a background is not typical for most elementary classroom teachers. Providing certification for elementary school mathematics specialists would allow schools and school districts to provide more opportunities for students at a younger age and to assist those students needing intervention. Elementary school mathematics specialists may teach across or within grade levels at the building level (e.g., be responsible for all fourth-grade mathematics). They could be responsible for mentoring teachers in mathematics at the building level and beyond, helping to direct the mathematics component of school-wide intervention programs and planning and implementing professional development programs in elementary school mathematics.

As mentioned earlier, only 17 states offer middle school certification in mathematics (Public Agenda, 2000). According to information provided by Maryland mathematics supervisors, less than half of the middle school mathematics teachers are certified as secondary mathematics teachers in the majority of Maryland school districts. This proportion is replicated in many states and is of great concern at a time when more and more middle school students are being exposed to important and sophisticated concepts in algebra, geometry, and proportional reasoning. In particular, this move toward algebra-for-many or algebra-for-all at the middle school level has presented both curriculum and staffing challenges, as more teachers without the proper training are assuming these responsibilities. Only nine states require all prospective middle school teachers to pass tests in their academic disciplines (Public Agenda, 2000). Mathematics courses necessary for middle school mathematics certification must provide teachers an in-depth understanding of the mathematics they will teach, and also provide a view of where that mathematics is headed – for their students (Ma, 1999).

Preservice teacher education programs should consider mathematics requirements more closely aligned to the candidates' content responsibilities. While most state and nationally approved programs in teacher education require that all prospective teachers possess substantive backgrounds in mathematics content and related pedagogy, actual requirements are often not specifically articulated or related explicitly to the level of mathematics that will be taught by these candidates. This issue seems to be especially critical, given the limited mathematics and mathematics education requirements of prospective early childhood and special education teachers. Specialty courses, such as those entitled "Mathematics for Elementary Teachers," are currently used to satisfy the mathematics content background requirements of many early childhood and/or elementary teachers. These courses attempt to address *all* content areas in the PreK-8 mathematics curriculum in one course or, in some cases, a two-course sequence. Teacher education programs should be able to verify that the mathematics content background required of prospective teachers at any level (early childhood, elementary, special education, middle school, and high school) is appropriate and sufficient.

A number of states and institutions responsible for teacher preparation are developing programs that include performance standards and alternative forms of assessment (The New Hampshire Preservice Education Review Project [PERP], 1997). To meet graduation and certification requirements, prospective teachers gather evidence to demonstrate their knowledge of mathematics and mathematics teaching (portfolios), use videos as evidence and as self-assessments, collaborate with a mentor teacher or supervisor, and continue to work in these areas after obtaining their first teaching position. Some states are granting initial certification to graduates of accredited programs but have developed a mentoring, review, and performance-assessment process that an individual must complete before applying for a long-term credential.

These certification requirements are characteristic of efforts underway to carefully link the preparation of preservice mathematics teachers to professional development programs, whether in the context of the Professional Development School movement (as colleges and universities collaborate with their school district partners), or as states develop plans for the initial and continuing certification of teachers. The nurturing and retention of teachers begins with the first course along the path to becoming a mathematics teacher and should continue throughout a teacher's career.

Conclusion

This discussion began with a quote from the Teaching Principle describing the intimate relationship

between mathematics teaching and learning. The teacher plays a critical role in the process of improving mathematics education for *all* students. The mathematics and mathematics education communities, parents, administrators, and mathematics teachers themselves have a responsibility to ensure that every student has access to the best and most qualified mathematics teachers and mathematics teaching. The *Principles and Standards* provide guidance to individuals and groups as they attempt to carry out their roles. Teachers need to "develop and maintain mathematical and pedagogical knowledge needed to teach students well" and "seek out high-quality professional development opportunities that fit their learning needs" (NCTM, 2000, p. 373). Teacher-leaders play a supportive role in the process and in particular "face the challenge of changing the emphasis of the conversation among teachers from 'activities that work' to an analysis of practice" (NCTM, 2000, p.375).

Mathematics educators and other higher education faculty need to develop professional development and graduate degree programs that help teachers at all levels grow mathematically and pedagogically. In addition, faculty should be active in developing school-based mathematics communities that involve a variety of constituencies. Finally, and maybe most importantly, the structure of most schools and university programs needs to change to accommodate the changing nature of teacher learning. In particular, programs need to make more explicit connections between undergraduate and school mathematics and provide opportunities for study and reflection in the practice of teaching.

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