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Working Toward a Continuum of Professional Learning Experiences for Teachers of Science and Mathematics

Susan Mundry, Barbara Spector, Katherine Stiles, & Susan Loucks-Horsley

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Abstract

This monograph is the result of a one-year qualitative study conducted by the National Institute for Science Education (NISE) of reform-oriented interventions, structures, and relationships in preservice and inservice education of teachers of science and mathematics. The study investigated 61 initiatives of reform activity involving teachers of science and mathematics preservice and inservice. The project found that a lack of focus, coherence, and alignment within and across preservice and inservice programs exists and persists for a variety of reasons. The paper describes a number of issues that are contributing to the lack of quality within the preservice and inservice experience of K-12 teachers of science and mathematics and to a lack of coherence in these experiences. These issues range from a lack of shared vision among principal providers of teacher preservice and inservice, entrenched and isolated roles and responsibilities for teacher development, cultural differences, including between the providers and receivers of teacher development, incoherence in design and content of teacher learning, and lack of coordination among mechanisms for quality control of teaching.

The study explored how these issues have been addressed across the initiatives and found efforts to build common vision, develop leadership, and create collaborative designs for professional learning to be among those strategies in use. The paper suggests these strategies could be used by systems of higher education, schools and school districts, collaboratives, professional developers, and/or other groups of teachers, teachers of teachers, and community leaders to improve the focus, coherence, and alignment of professional development for K-12 teachers of science and mathematics, thereby working to create and sustain a life-long continuum of teacher education.

There is a remarkable number of "pockets of innovation" working in many parts of the country to build and support a continuum of teacher development. This study illuminates some issues that need to be addressed and some directions that, if taken, could create a coherent, coordinated professional development system for science and mathematics teachers.

Executive Summary

A principal but somewhat neglected element of current reform is the creation of a coherent set or "continuum" of career-long learning experiences for all K-12 teachers of science and mathematics, primarily to improve teaching and learning in the classroom. This continuum would define the practices and life-long learning patterns needed to develop accomplished teachers who remain learners long after their preservice years. Such a continuum would offer clearly defined—designed and coherent—pathways of educational experiences for teachers from the time they decide on teaching as a prospective career. Science and/or mathematics content as well as pedagogical content knowledge would be addressed, as would where such knowledge is best developed along the points of a teacher's career. Such a continuum would need to be embraced, implemented, and sustained by the systems in which teachers learn and work—principally postsecondary institutions in which teachers are taught and school systems in which they teach. Teachers themselves would need to be both professionally and personally invested in this continuum of learning, from the very beginning to the very end of their careers.

During a one-year study of the connection between preservice and inservice education of K-12 teachers of science and mathematics, the professional development project of the NISE confirmed in part the earlier findings of others that such coherence does not exist at present. Studies by the National Commission on Teaching and America's Future (NCTAF, 1996), Raizen and Michelsohn (1994), and Goodlad (1990) found a lack of coherence in teachers' educational experiences from the time teachers declare a major through certification, actual teaching assignments, and professional development opportunities. The NISE study examined what reform-minded strategies are in place to address this lack of coherence within and across learning experiences for teachers. The project initially examined 10 reform initiatives at various locations across the country that are engaging in one or more interventions or mechanisms to improve the quality of preservice and/or inservice learning opportunities and to close gaps within and between them. While some of the initiatives examined were found to be addressing some of the challenges involved, none was addressing all of the challenges. Results of this initial exploration suggest that improving the focus, coherence, and alignment along a continuum of the preservice and inservice experiences of teachers would broaden teachers' instructional and assessment repertoires by deepening their knowledge of content and of students' thinking and learning. This progression of teacher learning is necessary to achieve the vision of content learning in science and mathematics for all students to national science and mathematics standards, and the progression should be well-grounded in credible research on how students learn science and mathematics.

After its initial study of the 10 initiatives, the project gathered information from 51 additional sites of reform activity involving preservice and inservice teachers. It found that a lack of focus, coherence, and alignment within programs as well as across programs can exist or persist for a variety of reasons, including the well-documented separate cultures, goals, and organizational structures of preservice and inservice education. Key issues identified by project participants include the incoherence in design and content of teacher learning experiences and uncoordinated quality control mechanisms. The study then explored how these issues have been addressed across the initiatives and found efforts to build common vision, develop leadership, and create collaborative designs for professional learning to be among the successful strategies. These strategies could be used by systems of higher education, schools and school districts,

collaboratives, professional developers, and/or other groups of teachers, teachers of teachers, and community leaders to improve the focus, coherence, and alignment of professional development for K-12 teachers of science and mathematics.

A Continuum of Teacher Development: Origins and Purpose

The vision that learning to teach should be regarded as a career-long commitment and that teachers should expect to develop professionally from their novice through their expert years is stated explicitly in national standards documents and, increasingly, is implied in state learning and assessment standards for students (National Council of Teachers of Mathematics [NCTM], 1991; National Research Council, 1996; Council of Chief State School Officers [CCSSO], 1992.) In fact, some reformers consider the concept of alignment in all aspects of teacher education to be central to reform (Webb, 1997).

The vision of ongoing professional development for teachers is grounded in the view that teachers' competencies grow progressively throughout their careers from novice to expert (Berliner, 1989.) More specifically, it is based on the perception that graduates of teacher preparation programs can enter the profession with basic teaching competence and the skills and dispositions needed to embark on a path of continued self-directed development (Anderson, 1997). As teachers gain experience, they build on their prior understanding; as they do, their competence in any given area increases and becomes richer and more diversified (NCTAF, 1996; Loucks-Horsley, Hewson, Love, & Stiles, 1998; NRC, 1996.)

The vision of ongoing professional development for teachers also recognizes that the changing circumstances in which teachers practice their profession create demands for them to develop additional skills and approaches (Berliner, 1986). Ongoing professional development is especially important for teachers of science and mathematics, as these fields develop and change rapidly. School science and mathematics must continually be updated for teachers and students to be able to keep pace. Further, research on pedagogy and how students learn science and mathematics concepts suggests new ideas and approaches for teaching that teachers must learn and practice (Ball, 1996).

Several other factors point to the need for a more cohesive and connected system of science and mathematics teacher education, preservice through inservice professional development. These include new policy initiatives, such as teacher recertification and assessment (National Board of Professional Teaching Standards, 1997; Educational Testing Service, 1995, 1996; Gilbert, 1997; Porter, Youngs, & Odden, in press).[1]

While policy initiatives and assessments are emerging that may eventually align teacher preparation, certification and licensing, and recertification, there is concern about current evidence that some teachers do not have the knowledge and skills they need to teach effectively

[1] The conceptions of teaching that underlie many of these assessments include

- Subject matter knowledge: that teachers have foundations in the structure and content of the subject matter they teach;
- Knowledge of students: teachers understand students' developmental levels, abilities, interests, culture, family, and community;
- Engagement of students in active learning: teachers are motivating and create engaging learning environments;
- Reflective practice: teachers assess events and decisions they make; and
- Pedagogical content knowledge: teachers understand how students learn and know appropriate learning activities and materials to meet learning goals (Porter et al., in press).

when they leave preservice. Teachers of science and mathematics face additional challenges today. For example, in part due to ambitious national standards, the current educational climate includes increased calls for all students to learn challenging science and mathematics. In contrast in the past, subjects like science and advanced mathematics were considered to be for intellectually gifted students only. Under the goals of national standards, teachers are expected to create environments for learning that are characterized by the following: inquiry and problem solving; application of knowledge across subject areas; collaboration among learners as they consider various sources of knowledge; and use of assessments that measure the progress of individual students in relation to new learning goals while also providing accountability for the effectiveness of teaching and schools.

Related challenges are calls for teachers to understand and educate a student population that is becoming increasingly diverse in cultural perspectives, experiences, expectations, and learning styles, which, in turn, requires teachers to create classrooms and learning experiences that work for each individual and for all (Hixon & Tinzman, 1990).

Finally, in part due to national standards and in part due to changing expectations for teachers, the structures and organizations in which teaching takes place have begun to change. Increasingly, there is a need for teachers and other educators to function successfully in, as well as to create, new centers of learning in their communities, with different clientele, including each other, and new learning goals, including the goal of high achievement by all students. In such settings, collaboration at all levels is critical, teachers become co-learners, and the process of building cultures and environments for learning replaces traditional classroom teaching. In such settings, continuous learning and adjustment to the changing conditions need to become routine functions.

All of these challenges require that teachers know mathematics and science content and how to teach it to diverse learners; that they become designers and engineers of the kinds of learning environments depicted in the national standards for both science and mathematics, with the full array of tools currently available and access to others as new tools emerge; and that they function effectively as members of a community that assesses what is working and why and that works intensely to produce the highest possible outcomes in all learners (Loucks-Horsley et al., 1998).

Overview of Study

This monograph is the result of a one-year qualitative study conducted by NISE of reform-oriented interventions, structures, and relationships in the preservice and inservice education of teachers of science and mathematics. The study was conducted in four phases; participants in each phase are identified in Appendix A. The phases are briefly described below, followed by the key findings from each phase and conclusions and recommendations.

Phase 1

Phase 1 of the study began with a review of recent literature pertaining to the reform of both preservice and inservice science and mathematics teacher education. Three NISE project staff with expertise in inservice professional development and three university faculty who work with preservice science or mathematics teachers read and responded to the literature review and identified issues and challenges in developing a career-long teacher education continuum. An issues paper was drafted. The issues identified by this group informed the issues identified and discussed in this monograph.

In addition, in Phase 1, the group identified people and places to contact to learn of reform initiatives, from redesigned courses to statewide mechanisms for better coordination.

From its work in Phase 1, the project noted that, while national standards documents call for teachers to have coherent life-long learning experiences, the literature suggests that the systems in place to provide teacher education and development lack focus and coherence within and between themselves. Specifically, the Phase 1 group learned that preservice experiences are not preparing teachers for the challenges of teaching. The benefits of years of effort spent studying content and developing "basic skills" in pedagogy are not nearly as large as they should be, as evidenced by teachers feeling unprepared to teach effectively and often dropping out of their profession (NCTAF, 1996; Salish Research Consortium, 1997). Once in practice, teachers need inservice professional development to build fundamental knowledge and skills and, in the worst cases, undo misconceptions and misguided pedagogical routines (Raizen & Michelsohn, 1994). However, when teachers do have inservice education, it is rarely connected to their learning goals or needs or to the curriculum and is predominantly offered in short-term workshops (Loucks-Horsley et al., 1998).

Phase 2

In Phase 2, the project team contacted 25 institutions or initiatives that were identified as experimenting with science and mathematics education reform initiatives and ideas. As the project team interviewed inservice and preservice educators, it found that most had not tried to link or build bridges between their respective efforts; however, through some of their reform initiatives, they had begun to see that change in only one part of the teacher education enterprise would not accomplish the goals of reform. Mechanisms and relationships that link preservice and inservice were needed to ensure that reform would take hold across the science and mathematics teacher education enterprise. This finding had been suggested by the Phase 1 literature review, and the interviews in Phase 2 reinforced it. The information gathered during the Phase 2 interviews was used to expand on and revise the issues paper drafted in Phase 1.

Phase 3

Of the 25 individuals interviewed in Phase 2, the project team identified 7 who were implementing ongoing strategies or initiatives to improve the preparation of science and mathematics teachers and who were linking preservice and inservice education in some way. Included were representatives of statewide systemic initiatives, teacher preparation collaboratives, professional development schools, reformed graduate programs, undergraduate programs, clinical development programs and courses, and teacher inservice projects. These individuals were invited to prepare and present briefing papers on their efforts at a subsequent work session. The information and insights of their papers are reflected in the "Issues" and "Mechanisms" sections of this monograph. Also during Phase 3, three additional initiatives were identified that were implementing strategies to address the continuum of teacher development. Representatives of the 10 initiatives were invited to submit papers describing their work.[2]

With the project team, the Phase 3 group confirmed, refined, and revised the issues identified in the draft issues paper from Phase 1 and elaborated on strategies they are using that seem to be narrowing the gaps in teachers' preservice and inservice education. The Phase 3 group also generated a list of other interventions or "initiatives" that might be bridging gaps between inservice and preservice education.

The draft issues paper was revised to include the input of the Phase 3 group. The "Issues," "Mechanisms," and "Conclusions and Recommendations" sections of this monograph reflect the work and key findings of Phase 3.

Phase 4

In Phase 4, the project team gathered data and additional information about issues from another 51 initiatives at institutions of higher education, regional clusters of higher education institutions, and statewide higher education initiatives involved in reform of science and mathematics teacher education identified in Phase 3. The project team gathered these data in open-ended face-to-face and telephone interviews, in focus group interviews, and from presentations and discussions at professional conferences.

Data and other information gathered in this phase are reflected primarily in the "Mechanisms" and "Conclusions and Recommendations" sections of this monograph.

Issues Related to Building of a Continuum of Professional Learning Experiences for Teachers of Science and Mathematics

Seven issues were identified in the first phases of the NISE study. These act as obstacles or barriers to improvements within preservice and inservice teacher education, greater alignment between preservice and inservice teacher education, and the kind of focus and coherence in teacher education as a whole. Addressing these issues could lead ultimately to the creation of a continuum of career-long learning experiences for teachers of science and mathematics. The issues are

- Weak "anchor points" on each end of the continuum;
- Lack of a shared vision among stakeholders for a career-long continuum of teacher learning;
- Entrenched and isolated roles in and responsibilities for teacher development;

[2] Exerpts from the briefing papers written about these initiatives are used to illustrate this report. These initiatives were not objectively evaluated for the efficacy of their work. See Phase 3 list in Appendix A for names of the individuals who described each initiative.

- Cultural differences;
- Incoherence in the goals, content, and design of teacher development programs;
- Uncoordinated quality control mechanisms; and
- The different educational needs of elementary, middle, and secondary teachers and of science teachers and mathematics teachers.

Weak "Anchor Points" On Each End of the Continuum

At present, both preservice and inservice teacher education can be characterized as incoherent and fragmented (Loucks-Horsley et al., 1998; Raizen & Michelsohn, 1994; Thompson & Zueli, 1999). In neither are the practices organized to carry out the vision of standards-based learning for all. For example, preservice programs vary in the degree to which they prepare teachers to teach to national standards for student learning, to teach in ways that incorporate inquiry and rich classroom discourse, and to understand the fundamental concepts of the disciplines they will teach. In teacher preparation programs, it is not unusual to find science and mathematics faculty members failing to coordinate with education faculty members and education faculty members failing to coordinate even among themselves. Science and mathematics courses do not model the pedagogy taught in education courses (Salish Research Consortium, 1997). One course does not build on another. In addition, many courses are taught by adjunct faculty who do not have deep connections to the program, and many clinical experiences are disconnected from campus courses. Individual faculty members have different visions and philosophies about teaching and learning and about the education of teachers. The moral and ethical obligation of teacher educators is still a question for some: Is it to train preservice teachers to survive in schools as they are today? (In this case their practices are likely to contribute to retaining the status quo.) Or is it to educate teachers to be decision-makers whose teaching is consistent with the reform movement and who can be agents for change to help schools reform?

Similarly, inservice professional development varies widely across the nation, from nonexistent to rich and sustained. Within a single district, it is typically fragmented, offering a potpourri of learning options for teachers, few of which provide the deep learning and support over time necessary to change and sustain new teaching practices. Inservice "providers," like teacher educators, have different visions and philosophies about teaching and learning, hold different convictions about what teachers need to know and be able to do, and subscribe to different methodologies for teaching and for professional development. Professional developers and curriculum personnel are separated and often offer uncoordinated, if not competitive, learning opportunities for teachers. Policies for teaching and learning and for testing and schooling differ from one local or state setting to another. And internal inconsistencies exist in individual districts and states, such as curriculum frameworks focused on deep understanding but oddly reinforced by high-stakes testing of fragmented knowledge.

The consequence of this lack of coherence in both preservice and inservice teacher education is that it is difficult to conceive of where to find supporting structures for a continuum of teacher development. The lack of quality in preservice programs at the beginning of a teacher's decision to be a teacher and then in inservice programs during a teacher's career vastly complicates the creation of a high-quality teacher education continuum.

Lack of a Shared Vision Among Stakeholders for a Career-long Continuum of Teacher Learning

The creation of a continuum of teacher education requires acknowledging that teacher learning must build and progress throughout a teacher's career. Yet the design of preservice programs often assumes students need to learn everything they will need to know to teach, and those responsible for inservice programs often assume that teachers know nothing when they begin their teaching careers. These assumptions can be valid: some teachers will not have significant learning opportunities after their preservice experiences, and many come to their new jobs without the skills and knowledge they need to teach. However, what prevails at present are programs that may not help and, indeed, may do harm: preservice that is "a mile wide and an inch deep" and inservice that does not build on prior experience or knowledge.

A shared vision that could come from discussions designed to bridge the gulf in perceptions and actions between preservice and inservice is needed. The topics of such discussions between preservice and inservice educators and supporting institutions would include what kind of knowledge is best developed in what settings with what resources and, consequently, the best roles for providers and institutions to play at the different phases of teacher development. At present, the lack of dialogue on these and other points inhibits the creation of a shared vision and the redesign of teacher learning as a career-long endeavor.

Entrenched and Isolated Roles and Responsibilities for Teacher Development

The teacher education system contains diverse sectors: for example, universities, liberal arts colleges, teachers' colleges, teacher centers, intermediate units, nonprofit educational organizations, and professional development organizations. Within these sectors, deeply rooted routines have emerged around who is responsible for what part of the teacher education system. For example, university science and mathematics faculty have seen themselves—and been seen by others—as producers of knowledge and professional experts, whereas liberal arts, teachers' colleges, and colleges of education serve as the "educators" of most of the nation's prospective teachers. Community colleges play a large, yet ignored, role in providing the content courses for a large percentage of teachers. Within universities, science and mathematics faculty view their responsibility as teaching content to students pursuing in-depth study in their disciplines. Few are asked to take or share responsibility to help prospective teachers apply their content knowledge to teaching in K-12 settings. At the local level, schools are seen as places that use knowledge produced by others by transferring it to students. Young people are seen as the students, not teachers. Many professional developers are translators or "linkers" who connect educational research findings to educational practice.

As a consequence of these clearly delineated and separate responsibilities, there is little reason for postsecondary institutions and K-12 schools to interact beyond the interfaces through which schools provide students for postsecondary study, and postsecondary institutions provide teachers to schools. As one initiative representative noted:

> It is ironic that universities are the primary agents of preservice education through their credentialling and degree granting functions, yet have little involvement in the ongoing development of teachers. (Trafton, p. 1)

Similarly, circumscribed roles exist in inservice, where schools "bring in" professional development providers, and the providers "come in" to do the work, yet neither the schools nor the providers go beyond their delineated roles to cultivate an ongoing relationship. As noted earlier, professional development and curriculum departments are often seen as separate functions. It is no wonder that structures that would foster more extensive interrelationships do not exist; they are not required.

There have been relatively few efforts in which parties responsible for developing and supporting teachers of particular content areas work together to define what the province of each is and what could be shared in the interest of creating a career-long continuum of teacher learning experiences and support. "Diversification of roles and responsibilities is a vital component of educational empowerment" (Shroyer, p. 2).

Cultural Differences Between Stakeholders

To build a bridge between two cultures is difficult; to build bridges between three or more is even more difficult. The separate cultures of community colleges, small colleges, large universities, professional development provider agencies, and schools form barriers to creating a continuum of career-long learning for teachers. Within colleges, universities, and schools, there are vast cultural differences among the science and mathematics faculties, education faculties, professional developers, and elementary-, middle- and high-school teachers. The differences include personal, professional, and institutional philosophies, missions, and approaches to education, as well as personal, professional, and institutionally sanctioned uses of time, norms, work styles, status, reward systems, and views of knowledge.

For example, in higher education settings, individual achievement and competition are highly regarded, and, in many, faculty are rewarded more for research and publishing than for teaching. Even when teaching is rewarded, the criteria used often do not reflect teaching consistent with national standards. Many liberal arts and teaching colleges place a higher value on teaching, but their incentive systems still reward scholarly research and publications over teaching. In schools, reward systems are based on years of service and graduate credits, not necessarily on teaching excellence.

Another example of cultural difference primarily between higher education faculty and teachers and their institutions involves time. Time is highly regimented in schools, structured by the needs and flow of young students; little time is allocated for teachers to work outside of their classroom. Use of time by higher education faculty and most professional developers is less regimented. Here, work styles and the setting's priorities are more flexible and individualistic than in schools. Consequently, within the education culture there are perceived differences in status among the worlds of higher education, educational research, and technical assistance and schools, where elementary teachers anchor the bottom of the status ladder and higher education science and mathematics faculty the top.

Views of knowledge differ among the denizens of these "worlds." Faculty at large universities are typically trained in research and place high value on knowledge supported by evidence of established validity. Teaching college faculty often focus on research, but it is on teaching and not necessarily in the disciplines. Professional developers range from the highly research-based to those who emphasize knowledge teachers can apply easily and quickly in the classroom. Teachers typically place a high value on the "wisdom of practice," viewing their colleagues as more valuable sources of knowledge than research.

A consequence of these differences is that key individual stakeholders in the teacher education system read different literature, belong to different professional associations, and attend different meetings. They speak different languages, value different knowledge bases, and hold different ideas in esteem. All of these differences create a vast cultural gulf between preservice and inservice providers and teachers.

Lack of meaningful interaction between individuals and communities due to cultural differences is a powerful barrier that makes it difficult for almost anyone involved in teacher education to envision a connected, career-long continuum of teacher education.

Incoherence in the Goals, Content, and Designs of Teacher Development Programs

Another major issue in establishing a career-long continuum of professional learning is the lack of understanding and agreement by all stakeholders about some critical factors. These factors include what teachers need to know and be able to do at various points in their careers; the optimal sequence of learning experiences that will facilitate development of knowledge and skills; and the roles played by different institutions, including certification agencies and policymaking bodies.

Goals. Of particular interest to science and mathematics education is what teachers need to know about the disciplines and in what ways they should learn (Kennedy, 1997). National standards documents address this concern (NCTM, 1991; NRC, 1996); however, the recommendations in these documents need to be translated into courses and other coherent learning opportunities that are required and/or offered to prospective and inservice teachers.

Content of programs. At present, there are many different stakeholders in science and mathematics education who make different decisions regarding what teachers need to know and in what ways they should learn. From individual university or college faculty to the institutions themselves, accrediting organizations, certification boards, teachers, professional developers—all have something to say about this topic, contributing to the incoherence and fragmentation of the teacher education enterprise (NRC, 1997; Howey, 1996). Most challenging in this regard is the nature of science and mathematics content courses, particularly undergraduate courses typically taught to majors as well as nonmajors in a large-class, lecture mode. One outstanding question here is whether teachers learn content best through these types of discipline-focused courses or, rather, should primarily learn about these disciplines through the study of teaching and learning in these disciplines. This question has created a dilemma for teacher preparation institutions. Do they offer different courses in science and mathematics for preservice teachers, thereby creating different "tracks," or do they redesign the courses in the disciplines to be more relevant for prospective teachers? Neither tracking nor wholesale redesign seems to be a satisfactory alternative. In addition, some institutions that educate teachers are still wrestling with the question of how best to help teachers understand cross-disciplinary connections among the sciences and also the potential for drawing connections across grade levels between science, mathematics, and other disciplines. One of the initiatives studied confronted this issue by rethinking the graduate mathematics education program. Trafton wrote,

> Existing graduate programs in mathematics education for teachers tend to have a small enrollment and represent a "higher education" model. They tend to be content driven, focus on transmission of knowledge, and have a "theory into practice" orientation in which connections to practice are encountered primarily in the context of studying advanced knowledge. Further, many teachers fail to make the connection between graduate programs and receiving help in becoming more effective teachers. The University of Northern Iowa's graduate program for middle school mathematics teachers focused on the teacher's continued development as a mathematics teacher . . .Thus the study of practice is legitimized . . . The model gives attention to complex connections among curriculum, teaching, and learning on the one hand and to the work of schools and classrooms on the other. (Trafton, p. 2)

Within the initiatives studied, there were a variety of approaches to changing courses on higher education campuses to make their content more consistent with the national standards. These approaches included creating a new course or program within a discipline, creating a course that was interdisciplinary among the sciences, creating a new course combining science content and pedagogy or mathematics content and pedagogy, creating a course that integrated all the disciplines, focusing the content in an existing science or mathematics course, reconceptualizing an existing science or mathematics course or science or mathematics education course, delivering a course electronically, and adding electronic communication to a course.

Pedagogical content must also be considered as one designs an effective and coherent continuum of teacher development. Currently, teachers and preservice students engage in a variety of experiences to help them learn to teach. These include field experiences, student teaching, professional development school participation, internships, and supported mentoring program participation. While these structures may be fine for building knowledge of teaching, what is inside of the structures—their content—needs more careful design and coherence to better contribute to teachers' learning about teaching.

Design of programs. Finally, to what extent do coordinated and coherent programs actually exist at any stage in teacher development—preservice, induction, or inservice? At each of these stages, different forces at work in teacher development programs act to prevent "programmatic" structure. Preservice programs often lack clear missions and coordinated sequences of learning, particularly between the disciplinary and pedagogical strands. Induction programs are few, and those that exist rarely do a good job of aligning the new teacher's needs with what a mentor can offer and the other professional development opportunities available to the teacher. Inservice programs typically offer fragmented, short-term learning experiences that, from the individual teacher's point of view, rarely amount to focused, sustained learning over time or learning that relates directly to the expectations and demands of his or her school, classroom, and students. The lack of programmatic structure in each of these components of teacher development works against the development of a teacher education continuum as a whole.

Uncoordinated Quality Control Mechanisms

Several quality control mechanisms come into play over the career of a teacher, including accreditation of the preparation program (traditional or alternative) and of university science and mathematics departments, teacher certification or licensure, hiring policies, teacher assessment, recertification, and recognition of accomplished teaching (such as career ladders, merit systems, and the National Board of Professional Teaching Standards certification). Each of these mechanisms has its own set of criteria, some of which—but not all—are generally geared to national standards (NCTAF, 1996). As they currently exist, these mechanisms do not assist in the development of a smooth, career-long system for teacher education. For example, certification processes contain expectations that teachers know all they need to know to teach when they start, but they don't, and that teachers do not continue to develop knowledge and skills over the course of their careers, but they do. If certification processes accounted for the growth and development of teachers, such processes would actually contribute to the growth of mechanisms that help teachers to grow and develop.

The Different Educational Needs of Elementary, Middle, and Secondary Teachers and of Science Teachers and Mathematics Teachers

Teacher developers interested in the continuum of teacher learning are often faced with hard questions regarding the differences in what teachers need to learn to teach different grade levels and to teach different content (in this case, science vs. mathematics). Traditionally, the former issue has been addressed by adjusting the number of university content courses: elementary teachers are required to take fewer courses than middle grades teachers (if there are any specific requirements at all for middle grades teachers), and high school teachers are required to take the most courses. However, as the question of what content teachers must know in order to teach their students to high standards becomes more focused, teacher educators are designing learning experiences that reorganize content in substantial ways (McDermott, 1990; Ball & Cohen, 1999). For example, if all teachers need to know the "big ideas" in the disciplines they teach, and know these ideas in some depth, how does the education of the third, eighth, and eleventh grade teacher differ? And, for each level, what is best learned in the undergraduate years? during induction? and throughout a career? Current conceptions of what teachers need to know to teach different grade levels are undergoing some scrutiny while traditional modes persist.

Differentiating what content K-12 teachers need to know and how they learn to teach it is complicated by the fact that women constitute the majority of elementary teachers. Often they have had negative experiences with science and mathematics in the course of their own education (Koch, 1990, 1993). The educational system may not have held high expectations for their learning of science and mathematics content, or engaged them in the processes of science. As a representative from one of the initiatives writes:

> For me, the course is a place where I create and offer opportunities for future teachers to construct a framework and some initial knowledge for their science teaching. The majority of students in

> this course are women who have had unpleasant experiences in previous science learning experiences, have had few opportunities to learn science with understanding, and have some of the same preconceptions about important "big ideas in science" as do 3rd and 4th graders. They usually lack both feelings of personal mastery in science and feelings of connection to the scientific community. (D. Smith, p. 1).

Thus, the attitudes and culture of a significant number of people attracted to teaching in elementary schools complicates the issue of what they need to learn and how they need to teach and how both might be addressed through teacher development (Spector, 1997).

Teacher development must also recognize differences in teaching goals and demands of the various grade levels. Where elementary teachers tend to be more focused on children's overall development than on developing content knowledge, teachers of grades 9-12 often focus more on preparing students to go on to study higher mathematics and/or science in college. In addition, elementary teachers are responsible for almost all content instruction for their classes (which can include up to 35 students in the course of an academic year), middle-grade teachers often share responsibility for content instruction for a group of students (80-100+), and high-school teachers almost always focus on a particular subject, but may also see 120 to 180 students each week of a given term. These different contexts are often ignored as teacher developers—at all levels—focus on content and instructional strategies. And few ask the question, How are these best addressed in preservice, during induction, and over the course of a teacher's inservice career?

Finally, teacher development also must recognize differences between science and mathematics education. For example, mathematics has traditionally been an accepted and valued part of the school curriculum at the elementary school level, while science has not. The science education community is still struggling to find its place in the curriculum, especially in elementary schools, where science is taught less frequently than mathematics.

Identification of these seven issues served to sharpen the search for strategies being used to close the preservice/inservice gap. The next section discusses what was discovered in that search.

Mechanisms for Building a Continuum of Professional Learning Experiences for Teachers of Science and Mathematics

The first step in building better connections between inservice and preservice—and, ultimately, in constructing a continuum of career-long teacher education—is for those who are responsible for teacher education to elaborate on and analyze the issues outlined above and to communicate across the inservice and preservice boundaries to identify ways to work together to address these issues. This section describes nine mechanisms that emerged from the study of 61 initiatives that address these issues in some way. Examples that are included in the discussion of the mechanisms are taken from papers prepared by representatives of the 10 initiatives involved in Phase 3 of the study. The 10 initiatives are:

- The elementary science teacher education program, fifth-year internships, and science study groups (Michigan State University and Averill Elementary School)

- Supporting mathematics teacher development with narrative cases (University of Pittsburgh Learning Research and Development Center)

- K-12 preservice science education program (University of Northern Colorado)

- Middle grades mathematics teacher graduate program (University of Northern Iowa)

- Columbus regional mathematics collaborative (Georgia State University, Columbus, GA)

- The West Genesee/Syracuse University Teaching Center

- Statewide K-12 and postsecondary teacher development programs (Louisiana)

- Statewide K-16 education reform initiative (SciMath^{MN}/Minnesota)

- The Salish I Consortium Research Project

- Professional development schools developed through university/local school collaborations (Kansas State University and three school districts: Manhattan-Ogden, Geary County, and Riley)

The Phase 4 initiatives included teacher education courses and programs, teacher enhancement initiatives, reform networks, professional development schools and teacher support structures. Together the initiatives range from those that are small in scale and focus on a particular university or school to those with a broader scale—statewide—and broader focus—K-16, for example. Interestingly, they all share certain characteristics. First, they all pay attention to *both preservice and inservice* teachers and, by providing opportunities for their learning in close proximity to each other and to the classroom, serve to narrow disconnections between preservice and inservice. Second, most of these initiatives have a *vision of effective teaching and learning* of science and/or mathematics that is *shared* by all participants in the initiative. This shared vision in all its particulars permeates the content and nature of the professional learning that takes place through the initiatives. The vision is often supported by policies, but is realized through the resulting new, or reformed, professional development experiences of teachers, which help teachers model the vision in their teaching design and in their teaching of students.

Third, these initiatives are *collaborative* and employ *collaborative structures* that bring the worlds of preservice and inservice together. Among the initiatives studied, collaboration includes commitment to a common set of goals and to playing a substantial role in reaching the goals of the shared vision. At the policy level, collaboration occurs with other sectors of the education community, among national, state, and local policymakers, with the scientific and mathematics communities, and with local communities and parents, which requires effective *communication*. Throughout these initiatives, collaboration occurs in establishing and operating professional development structures, in designing, sponsoring, and conducting professional development experiences, and in planning and enacting teaching.

Another feature that was found to be common to many initiatives is clear *leadership* that promotes and guides the vision, manages components efficiently and purposefully, and attends to the politics of the community and the authority structures that need to support and sanction their efforts.

In this study, nine mechanisms emerged that are being used to address one or more of the issues outlined in this paper and begin to build important connections between preservice and inservice education.

- Shared vision of teacher development
- Communication and collaboration
- Redesigned clinical settings and beginning teacher programs
- Materials for teacher development
- Certification and assessment
- Rewards and incentives
- Professional development for higher education faculty and inservice professional developers
- Leadership
- Resources

Figure 1 (see Appendix B) indicates the mechanisms used by each initiative.

Shared Vision of Teacher Development

In many cases, the initiatives examined in this study used national standards documents to help frame a vision and to identify and mobilize key players. Their emphasis was not on wholesale adoption of the vision set forth in these documents; rather, they used the documents to come to a shared understanding of their own goals in their own context and to build a vision for their particular initiative. This practice was seen repeatedly among successful initiatives. Deborah Smith wrote:

> First, each community is engaged around a common set of state and national reform documents and resources. This makes for common knowledge and common goals, and the ability to have common talk around those ideas.
>
> Second, the teacher preparation program affords opportunities for teachers at a small number of schools to work closely with TE faculty on improving their own teaching and on designing a program to support new teachers in their teaching. These teachers then provide existence proofs of attempts to teach in reform minded ways, for our students and for other teachers. (p. 4)

Creating a shared vision is a process of constructing a mutual image—in this case, of what the teacher development system should look like to reflect the national standards. In the interventions examined, the creation of a vision was a learning process. Creating a shared vision looked very similar to processes used in a constructivist classroom. Each individual's prior concept of good teacher education was shared and explored within a group that often represented very diverse beliefs and backgrounds. People were empowered to move from their individual beliefs to a common vision by sharing information, such as national reports, standards documents, and research results from which to gather data to confront their beliefs. Although time consuming, the process of learning to communicate across diverse groups about something so basic as vision was critical to building the relationships needed to sustain new efforts. Over time, the different players explored the extent to which their ideas were related to each other's vision and to the national vision. As Paul Trafton wrote:

> Initially, rather than focusing on the courses we felt should be included in the program, we spent substantial time developing a cohesive philosophy about mathematics, about teaching and learning mathematics, and about the field of mathematics education that defines the program . . . we wanted our work to be program-driven rather than course-driven. (p. 3)

When groups learned about each other's ideas and philosophy, they built an equal playing field that mitigated the effects of differences among the participants and differences in potential levels of influence on the group due to, for example, professional positions, perceived expertise, control of resources, sponsorship, alliances, commitment level, and so on. The processes used in the various interventions to establish a shared vision had many things in common. The groups usually had at least one person knowledgeable about science and/or mathematics reform who provided resources to build a common knowledge base about reform initiatives, national standards, and research on learning and teaching. Several of the initiatives created opportunities for the players to read and discuss the meaning and significance of these resources to them and to their efforts.

In some cases, hands-on experiences with learning opportunities consistent with the vision were structured for the participants. For example, Kerry Davidson wrote:

> LASIP inservice projects, USL preservice mathematics courses and methods courses and parish wide inservice programs have all been rooted in a common vision and common goals—faithful to national standards and formulated in collaboration with K-12 teachers from seventeen . . . projects. (p. 7)

This statement was followed by a discussion of how those experiences related to the vision in the documents. External facilitators were often used to guide these meetings and to help the group learn from their interactions with one another.

In the statewide interventions that were studied, small groups drafted elements of a vision and then distributed them for feedback to other groups. Focus groups were organized on individual higher education campuses and in individual departments to collect feedback. In other cases, regional groups of educators reviewed drafts and gave feedback. Additionally, drafts were distributed to stakeholder groups for their input. Several rounds of feedback and rewriting were usually required to develop consensus.

Each initiative that focused on building a new and shared vision of teacher development reported that they needed a substantial amount of face-to-face meeting time to develop and enact the vision and that the time required was usually much more than they had anticipated. The statewide initiatives of Louisiana and Minnesota as well as smaller scale initiatives working across the boundaries of universities and local schools, created new structures through which this interaction could take place and within which key players could form new relationships critical to bridging the preservice and inservice worlds. The structures created ranged from informal networks of teachers and professors to cross-campus committees of science, mathematics and education faculty to state-level policy groups, including state board of higher education members, state commissioners (or superintendents) of education and university heads. Time to meet and the creation of structures that encouraged interaction and the formation of new relationships among key players were critical. The availability of guidance and expertise and effective communication among stakeholders also assisted the creation of a shared vision.

Communication and Collaboration

In many of the initiatives studied, the process of interaction to create a shared vision was time consuming, because it involved not only developing new relationships, but also learning to communicate and understand others' language, contexts, issues, and the "ways of thinking and doing." Although people may have worked together for long periods, as they worked on reform issues they found they needed to learn to communicate better. A major challenge to such communication was the fact that the worlds of science and mathematics education do not have a common language (Anderson & Mitchner, 1994; Spector & Brunkhorst, 1999). Historically, science, mathematics, and education disciplines have developed independent from each other.

Stakeholders in the initiatives studied were grounded in these different disciplines, each of which has its own research paradigms. Their departments, colleges, universities, school districts, individual schools, informal education agencies, businesses, industries, and communities all have their own distinct culture. It was no surprise that stakeholders who were trying to collaborate nonetheless found that they had different assumptions, and even different meanings for the same words, and needed considerable time to negotiate common understanding.

In initiatives where different stakeholders and institutions worked together most successfully, shared language was negotiated that facilitated understanding of each other's worlds, strengths, capacities, constraints, and operating norms. These negotiations involved developing new relationships, clarifying meanings of words, and developing shared meanings. Elements involved in the process included (a) understanding each of the collaborating units as a freestanding whole, (b) understanding the similarities and differences among them, and (c) understanding what happened at the interface where the units meet. Many initiatives found that setting up tasks that are appealing to multiple groups often served to facilitate communication across boundaries.

In Salish I, a research project involving several institutions, communication was facilitated when science and mathematics teacher education initiatives:

- “Built in significant amounts of time to address communication issues;
- Designed strategies that explicitly attended to clarifying and negotiating language issues;
- Examined multiple aspects of contexts in which people operated;
- Helped people identify and confront their assumptions and beliefs; and
- Involved communication experts as facilitators for meetings to ensure that members could dialogue effectively and understand one another.” (Spector & Brunkhorst, p. 15)

Collaboration was common to the interventions studied. Most initiatives established a formal or informal structure that brought individuals representing preservice and inservice together to plan and, in some cases, govern the work of the initiative, often with support from grant funds. The structures ranged from the more formal, such as professional development schools, to the more informal, such as advisory groups. Two of the initiatives studied (Syracuse University and Kansas State University) operated professional development schools. These initiatives demonstrated very high collaboration. As Shroyer wrote:

> Both the Elementary Education and the Secondary Education PDS Models are based on the belief that teacher preparation and school reform are the joint responsibility of institutions of higher education and school systems. PDS participants have acknowledged that teacher preparation involves all groups of professionals who in any way touch the educational lives of teachers. (p. 2)

Another example of a collaborative structure is a seminar course found at the University of South Florida. This university runs a seminar focused on the learning and teaching of science that brings together undergraduate students; graduate students at the masters and doctoral level; professors from the College of Education; a professor from the psychology department in the College of Arts and Sciences; and a visiting distinguished professor of biology and science education from another university. Together, they explored perspectives on how people learn science and the implications for teacher learning at all levels. The seminar discussions produced new images of the learning experiences science teachers need throughout their careers, e.g., for teachers to engage in learning science as they will be expected to teach it. Through the seminar, the faculty identified the need to make courses better reflect how children and adults learn science and more relevant to the realities of teachers’ learning needs, both as graduates and undergraduates. The seminar also created the opportunity for inservice teachers in graduate programs to interact with preservice undergraduates, modeling a culture of teachers talking with one another about teaching and learning.

Other initiatives were linked to state sanctioned systems for collaboration. For example, Georgia has an initiative called the P-16 Council that encourages universities, two-year colleges, the technical schools, the community and the school systems to work together for education Lindquist, p. 2).

Other collaborative structures found in the study that break down barriers between preservice and inservice education at the college level, and inservice and ongoing professional development within local schools, included school-university partnerships such as those involving Michigan State University and Syracuse University. One university created a new office of school-university partnerships within its school of education. That office is now an established part of the university. In some cases, school-university partnerships are built around thematic interests, such as curriculum integration or redesign of particular courses; in others, partnerships formed steering committees to reach out to potential new partners by hosting and supporting cross-campus conferences on reform in response to state level directives. Another initiative described its collaboration with local schools:

> The Columbus Regional Mathematics Collaborative (CRMC) works closely with the vocational high school as a professional school for mathematics...there is time provided for discussing the teaching and learning of mathematics...undergraduate secondary mathematics students are placed in this school with these teachers for their practicum. (Lindquist, p. 1)

Some collaborative structures were based inside universities; others were based in schools; and still others were based in entities external to any of the partnering institutions. Several university-based structures included school teachers, and some school-based structures included university faculty. Some structures were created and based within a particular university campus across the different departments with authority to change teacher education programs. Others went beyond a particular campus to include two-year higher education institutions as partners.

When structures started out with university/college staff only, at some point this staff realized it needed input from teachers and other practitioners. The involvement of the teachers was often limited at first, but then grew as communication increased; participants discovered value in each other's knowledge base, and good will developed. In one example, teachers were first involved when they were asked to react to a redesigned course syllabus developed by university faculty. The teachers' involvement then grew to include assessing course implementation, co-teaching a redesigned course, and planning future courses and programs.

Often initiatives used advisory boards as the structure for collaboration. Advisory boards have often been comprised of external experts who come together to advise projects on planning, and then perhaps to keep track of the project's accomplishments at milestones. But the advisory boards for the collaborative initiatives studied were more directly involved in their initiatives and were more active in design as well as implementation. For example, some advisory boards actually initiated and sustained new entities rather than becoming an arm of any one existing entity such as a state department of education or a school district.

A new kind of collaborative advisory structure, called a National Visiting Committee (NVC), was seen in the National Science Foundation-funded Collaboratives for Excellence in Teacher Preparation. These were significant because they brought members of the preservice and inservice communities together to provide input to the design and implementation of the Collaboratives.

In some of the initiatives studied, less formal collaborations exist among individuals. For example, teachers and higher education faculty developed courses together; faculty within the same discipline worked on reforming courses and curriculum as well as the structure of clinical learning experiences to be more in line with reform minded instruction; faculty and professional developers mentored each other to learn, for example, how to use innovations such as cooperative learning in college classrooms; faculty conducted research, wrote papers, and made presentations together; teachers, faculty, and undergraduate students worked together on R & D projects in a research and development center; and teachers and faculty together taught teachers in professional development schools.

Many factors appeared to contribute to successful collaboration in the initiatives studied. Some of these factors, corroborated by a recent research study (Spector, Strong, & King, 1996), include (a) equally empowering all collaborating stakeholders, (b) mutually valuing each other's knowledge bases, (c) believing there is synergy (that the collaborative product is greater than the sum of its parts), (d) being committed to the collaboration, and (e) trusting each other.

Redesigned Clinical Settings and Beginning Teacher Programs

Many of the initiatives studied recognized that the early experiences teachers have in schools during their preservice and beginning teaching years are critical shapers of their own teaching. In some cases (Syracuse University, Michigan State University, Kansas State University), clinical and beginning teaching experiences were designed and constructed so that practicing and beginning teachers could receive exposure to the philosophy of teaching and learning at the school, and modeling and coaching by accomplished teachers, while experienced teachers could continue their own learning. As Yarger-Kane wrote:

> The Professional Development School is designed to provide a program for the development of novice professionals and for the continuing development of the experienced teacher. (p. 2)

In some cases, to support this work, the accomplished teachers themselves received ongoing professional development, including learning experiences that were embedded in their jobs; that is, they took place in the course of the school day, and often in the process of teaching. These activities included action research projects or piloting or field testing new curricula, as well as summer inservice workshops and institutes, special semester-long courses, inquiry academies for teacher leaders, opportunities to study teaching practice, inclusion of teachers as part of advisory boards for designing and implementing new university courses, and teachers working as staff in science and mathematics summer camps for children.

A common element of the redesigned clinical settings was that they provided preservice students with ample exposure to schools, novice and experienced teachers, and teaching situations. As Gapter wrote:

> PTEP [the teacher preparation program] established a partnership with local secondary schools for three semesters of exposure and work with secondary students. Over the three semesters the preservice students develop understanding of, first, the secondary school culture, next, the teaching of content, and, third, methods of teaching. (p. 1)

Action research projects conducted by beginning teachers or preservice students with experienced teachers provoked reflection; participating teachers wanted to know why what they did work sometimes and not others and also how to improve their work. Situations like these bring beginning, novice, and experienced teachers together, which one initiative says makes sense because

> similarities between role groups also exist. Preservice, novice, and experienced teachers have common concerns about addressing the learning needs of all children (Yarger-Kane, p. 2).

Working together in new ways often led teachers to change their own view of themselves from knowledge consumers to professionals able to produce knowledge and able to share responsibility for teacher education. The beginning of an important connection was built between preservice and inservice in one initiative when university faculty conducted action research studies with their graduates, in this case to learn about the impact of their teacher preparation programs on their own students' performance as teachers and on the learning of the teachers' students.

Another initiative used a "template of systematic inquiry" for both inservice and preservice education. The template guided the "study of practice," creating clinical settings consistent with reform and a bridge between inservice and preservice education. In this initiative, teachers in a school identified a problem they were encountering, generated questions about it, and looked for outside resources to answer the questions. Since teachers often do not have the time to search for resources, a university faculty member assumed responsibility for locating appropriate resources and materials to meet the teachers' needs. University personnel and professional developers with relevant expertise were among the resources the faculty member connected to the teachers. In the study, it was found that university coordinators of professional development schools commonly serve in this role for the teachers in their schools. Spector and Spooner (1993) suggested that local science supervisors can also serve in this role to link teachers to resources. The teachers then used the resources to answer their questions and to solve their problem. This ongoing relationship helps teachers in practice gain access to resources and new information and helps professional development school faculty better understand the inservice needs of teachers.

This initiative also found another use of systematic inquiry, this time one that can build better connections between what preservice students learn and what they will need to learn to be effective teachers. Students in one methods course learned their teaching methods in a structure designed around the questions preservice teachers raise when they are in school settings. Because the preservice students were moving back and forth between school experiences and university classes, the initiative found that reflecting on the experiences in one setting helped the learners build new understandings in the other. In this way, preservice students were led to investigate within their methods course the questions that will likely come up for them as they begin to teach.

Materials for Teacher Development

Fairly recently, new materials that bring the realities of the classroom into teacher development—for preservice, inservice, or both—have been emerging. These materials include representations of practice, such as classroom videos and narrative cases of teaching dilemmas. In some initiatives, teaching cases were useful; they helped facilitate inservice teacher discussions with preservice teachers about how teaching decisions are made. In other initiatives, reform-oriented student curriculum materials were used to help teachers learn science or mathematics content. In some cases, student work was analyzed and discussed to help teachers better understand student thinking. As Deborah Smith wrote:

> The [Michigan science resources curriculum] network will contain science curricula that have been field tested in classrooms and for which we have pre- and post- assessments and children's work to support the claim that they are beneficial for children's understanding of particular central scientific ideas. Our goal is to provide curricular support—along with videotape clips of classroom lessons, transcripts of interviews with children, examples of children's work and commentary from teachers who have used the units—for both future and practicing elementary teachers who wish to engage in reforms in science teaching and learning. (p. 3)

The value of such materials in improving teacher development lies in part with the fact that they can be shared with preservice and inservice teachers alike to provoke discussions and reflections about what good teaching looks like. They help bring to the surface the kinds of things good teachers are conscious of, such as whether even reform-oriented curriculum materials are actually working with their students, what their students are thinking, and where to go next. A participant in this study, a principal in a new project to design case materials for use by preservice and inservice educators, wrote,

> Case methods are particularly promising as a means of facilitating the development of content knowledge and supporting inquiry into classroom practices. (Smith, M., p. 2)

At present, the National Science Foundation is funding the development of additional teacher development materials to create focal points for teacher learning that can bring prospective teachers closer to the classroom and give beginning teachers practice in recognizing and analyzing effective learning and teaching. One example comes from Trinity College in Burlington, VT, where video and print materials are being developed to help preservice educators and professional developers teach teachers how to conduct ongoing assessment of student thinking and learning in the course of instruction. In addition, Horizon Research's TMAT project is identifying and placing on the World Wide Web materials that will be useful to preservice teacher educators and inservice professional developers alike.

Certification and Assessment

Increasingly, teacher assessments are being used for initial certification as well as for recertification and to pinpoint areas for teacher development. For example, the Certification and Accreditation in Science Education (CASE) project is developing standards and indicators to describe teachers' professional growth that builds on the work of the Interstate New Teacher Assessment and Support Consortium (INTASC), which has developed standards for beginning teachers, and the National Board for Professional Teaching Standards (NBPTS), which has delineated standards for accomplished teachers (Gilbert, 1997). The INTASC and NBPTS standards are consistent with each other and with national standards for K-12 students; i.e., the *National Science Education Standards* (NRC, 1996) and the standards of the National Council of Teachers of Mathematics (1991). These documents were used extensively by the SciMathMN initiative to build a vision of what teacher education should look like.

Both INTASC and the NBPTS are developing assessment tools to measure teachers' performance. In addition, the Educational Testing Service (ETS) has created the Professional Assessments for Beginning Teachers (PRAXIS) series of teacher assessment tools that address basic skills, content and pedagogical content knowledge, and performance (ETS, 1995); CASE standards will be used by the National Council for Accreditation of Teacher Education (NCATE) for teacher preparation program accreditation; and INTASC standards are being used by states to help them redefine certification and licensing procedures.

Issues of certification in mathematics education are somewhat different from those in science education. Teachers who are certified as mathematics teachers are expected to know the various areas of mathematics, such as algebra and geometry. Teachers who are certified as science teachers are usually certified in a specific discipline of science, such as biology or physics. Some are certified in general science but are expected to have some depth in each area under that umbrella. Some middle-school teachers are certified in a content area; others have a general certificate like elementary educators. Certification is important because it "lives" between preservice and inservice; it can serve to connect the two or it can broaden the gap.

This study found that, in Louisiana and Minnesota (the two statewide initiatives studied), changes in state teacher certification served to help interest many higher education faculty in the reform of teacher education across the board. Faculty first became interested in establishing certification criteria and then, afterwards, in reforming their teacher preparation programs.

All of these changes occurred after student standards had been established and a standards-based high-stakes assessment developed, helping to make it clear that both initial and continuing certification for teachers needed to be based on more than how many university courses one has taken. For example, as a result of Louisiana's reform initiative, prospective teachers are now required to pass a basic skills test, a content examination, and a pedagogical examination to obtain a one-year preliminary certification and then, after one year of teaching, must pass a performance test in order to obtain full certification.

Certification is available through many alternatives to the traditional undergraduate preparation program. Some of these alternatives target retired or career-switching scientists and mathematicians, others constitute a fifth year of university preparation—often with an internship or part of an induction year. Drake (1997) points out that alternatives range along a spectrum from "quick-fix" certification options to alternative route programs. Alternative route programs, which often include a master's degree, hold to rigorous state standards and provide the critical knowledge base at universities (Darling-Hammond, 1990). Quick-fix options are usually created in response to a shortage of teachers and premised on the assumption that teaching is a "walk-in" job that requires little in the way of preparation except content knowledge (Wise, 1994; Drake, 1997). A concern about these options is that they reduce the amount of professional preparation, allow developers to get around state standards, and do not contain the knowledge base necessary to produce a fully qualified teacher (Darling-Hammond, 1990; Drake, 1997).

Although some teacher development alternatives are clearly problematic, a common feature of most is that they require teachers to take courses during their first year of teaching. This practice helps to bridge the gap between preservice and inservice education and create the expectation that teachers continue their education. Having responsibility for one's own classroom all year creates a living laboratory for a new teacher, which establishes relevance, immediacy of need, and use for learning. In the best cases, teachers establish a pattern of reflection and inquiry about teaching, which contributes to their continuous learning and growth, thereby bridging the gap and beginning to build a continuum between learning what is needed to start teaching and learning throughout a teaching career. Further, candidates in an alternative program usually go on to teach in the community in which they studied. Extant connections to the institution of higher education where they studied can then serve as a mechanism for their continued professional development.

Rewards and Incentives

Many university-based initiatives in the study discussed the need to reward faculty in tangible ways—especially during the tenure and promotion process—for their involvement in reform of science and mathematics teacher preparation. However, there was little evidence of administrative support for such a change. In fact, there was evidence of the opposite: frequently noted was the continued use of traditional evaluation forms to measure faculty performance at the end of courses—forms that do not reflect the value of teaching. Deborah Smith observed that

> the rewards structure for elementary teachers, College of Education faculty, and College of Natural Sciences faculty continues to work against the long hours required for collegial work that supports continuous professional development in science teaching at all levels. (p. 4)

In one initiative, changes at the state policy level now mandate that all universities show evidence of reform in science and mathematics teacher preparation programs. While this mandate has potential to stimulate changes in the reward systems for faculty at individual institutions, not enough time has passed to ascertain actual impact.

One of the most difficult challenges in putting together a life-long teacher education continuum is getting schools to contribute to the support of teachers involved in reform of teacher preparation. In some initiatives, teachers who had been selected to work with university faculty to improve teacher education commonly found that their teaching colleagues did not approve. In fact, the selected teachers felt rejected in the social milieu of the school. In addition, many school administrators were reported as voicing the position that "a teacher's job is with the kids in class."

On a more positive note, some local district practices in this study have had a positive effect on teacher learning; for example, raising salaries as teachers earn graduate credits. In addition, many states in which these initiatives exist have set requirements for ongoing professional development and for teachers to earn professional development credits. In the professional development schools studied, time is provided for accomplished teachers to work with beginning and preservice teachers in the schools. These activities are seen as part of the teachers' regular responsibilities, and time for carrying them out is valued. This practice is also seen in other countries such as Korea, Canada, and Australia, where schools are paid to mentor preservice students during their practicum.

Professional Development for Higher Education Faculty and Inservice Professional Developers

Many of the initiatives studied cited the need for faculty and professional developers to have continuous learning opportunities. In the higher education programs in particular, faculty need professional development to help them teach in reformed ways. Several initiatives used professional development as a means for building a continuum across preservice and inservice education; activities ranged from the more traditional forms such as attending national and state science and mathematics education conferences and holding brown bag lunch presentations to more innovative forms such as formal mentoring and collegial coaching between teachers and faculty in the professional development school settings. These latter examples were more long term and robust and appeared to show more promise for building the teacher education continuum, because they place faculty and teachers together sharing responsibility for both preservice and beginning teachers. In several other initiatives lead teachers who perform professional development functions in their schools received professional development to help them carry out their role. However, in these instances there were no explicit links made between preservice and inservice.

Leadership

In the initiatives studied, leadership to bridge the gap between preservice and inservice education came from different levels in the enterprise, from individual professors or teachers to state boards for K-12 education to boards of regents for higher education. Regardless of which part of the enterprise their leaders came from, the initiatives tended to have a core of enthusiastic, committed people, at least one of whom was steeped in the K-12 reform before the beginning of the teacher education intervention. The leadership in higher education often had extensive experience teaching science or mathematics in K-12 institutions prior to working in higher education. Leadership for professional development schools was usually shared between the university and schools. The stimulus usually came when a university person contacted a school principal or teachers and suggested that they explore the possibility of a working relationship; then a team of teachers and university faculty developed the project.

The leaders of the various initiatives studied were not explicitly committed to bridging the gap between preservice and inservice education. Usually they convened to improve some aspect of science or mathematics education, but then began to work across the barriers of inservice and preservice because they were influenced by funding requirements, in the case of several systemic initiatives, or they were guided by national standards documents that called for actions across the teacher education system in the case of some of the smaller more localized initiatives.

Overall, the study found that leadership can come from many different parts of the science and mathematics teacher education enterprise and from different levels within it. Leadership often worked at making the preservice and inservice experiences for teachers more coherent and connected at the state and regional levels as well as in individual cases. For example, on one university campus, an education professor who had introduced science professors to the reform by inviting them to participate in her science methods class went on to help develop a master's degree program for teachers of science. A group was established to ensure that all the science and education courses developed for this new degree program were consistent with reform activities underway in the local schools. Inservice teachers had the opportunity to study further, to enhance their understanding of the reform, and to make their own classes better places for interns.

At all levels of leadership, changing relationships and/or creating new relationships through effective communication was at the heart of the work of the leaders. At the state level it was critical for formal relationships to change. In most cases leaders moved forward by using the distributed leadership style—involving and empowering all who wanted to participate in appropriate ways. Shared responsibility and support were necessary for the intervention to progress. Lessons learned from the initiatives studied relate to leaders regardless of their position in the education system. Perhaps the most common lesson learned was that leaders need to expect everything to take longer than planned. Other commonly reported lessons are reflected by the following list, which was developed by SciMathMN:

- Establish a community with a broad base of support
- Always be on the lookout for new recruits
- Develop a shared vision of what you want to accomplish
- Identify enthusiastic committed leaders for your project
- Distribute leadership and responsibility among all involved
- Talk with each other often
- Demonstrate respect and value all members of the community and their beliefs
- Work with your team in a moral way
- Be a part of the overall process of change
- Be prepared for setbacks
- Recognize that change is a slow process
- Recognize that feeling inadequate is part of the job

Another common lesson reported by the initiatives was that, even when leadership for reform began at one level, overt commitments from other levels—presidents, provosts, deans, and key faculty in higher education institutions and administrators and teachers in local school districts—contributed significantly to establishing a culture of reform, particularly if the individual had credibility among the groups involved. In such a culture, high- level administrators understand the reform, articulate their understandings, and are publicly active in discussions of the reform.

However, the turnover among administrators and faculty leaders in interventions caused significant setbacks for some of the initiatives. One administrator noted that every time an administrator changed, the progress toward reform went backwards. "It could be a 7 on a scale of 10 and it goes back to a 2." In one university, for example, a department chair supported the creation of a task force of university faculty, teachers, and school administrators to redesign the clinical portion of the university's teacher preparation programs, including those for science and mathematics. The task force worked for four years to create a new structure and obtain consensus from the appropriate stakeholders. Then the department changed, and the new plan was not implemented. After three years, the department's new chair suggested that a group should be formed to examine the clinical aspect of the existing program.

Turnover among school administrators also has the potential to cause problems. Superintendent turnover is very high, especially among urban superintendents who are barraged by political pressures to show quick increases in student achievement. As superintendents are replaced, so are their priorities and commitments, resulting in situations in which the school district reneges on its commitment to support reform initiatives. Many initiatives studied worked to build leadership at all levels—superintendent and school board, as well as at the teacher and building administrator levels—to find ways to make the vision of a continuum of professional development a reality.

Resources

Additional funds were required by all the initiatives to jump-start their innovative work. The funding mechanism used most often to start the teacher development reform initiatives was competitive grants from federal, state, and private sources. Federal funding agencies were the most popular direct source, principally the National Science Foundation and the Eisenhower program. Another source was federal money passed through by states in the form of grants. When matching grants were required (e.g., by federal funding agencies), legislatures and private business or industry usually supplied the necessary funds. Sometimes, when federal funds were not forthcoming, matching money that had been committed was used to launch the initiative. Once initiatives were up and running, continuation funding was usually raised/received from private sources—foundations or the business sector. In a few cases, the university paid for release time from a teaching assignment to enable a professor to work on the initiative. In a few cases, professors used their own time and minimal resources from their teaching budgets. On rare occasions, school districts contributed local funds or funds from grants they had acquired.

The study found that, overall, considerable resources are being spent on the development of career-long professional development for teachers in mathematics and science education. NSF is supporting collaboratives, systemic initiatives, and teacher enhancement programs; and the National Eisenhower Professional Development Program (U.S. Department of Education) is funding higher education institutions, school districts, and state departments of education to provide professional development opportunities for teachers and higher education faculty. In addition, it is common for portions of these NSF and Eisenhower grants to be used to support the formation of communities of learners in which preservice and inservice teachers and university faculty are working together toward a common vision that includes a career-long learning continuum for teachers of mathematics and science.

Conclusions and Recommendations

> While recent research underscores the critical role of the teacher in promoting student learning, we are far from creating the conditions for teachers to learn well and teach well. (Darling-Hammond, 1998)

What emerges from this preliminary study is that a coherent system for teacher education spanning the preservice and inservice years does not exist but is very much needed. Initial and small-scale efforts are underway that are exploring what it would take to make such a system a reality. This system would be guided by a clearly defined continuum of educational experiences for prospective, beginning, and experienced teachers. This continuum of learning would be characterized by a *designed and coherent* set of connected experiences for every teacher that would begin in his or her preservice years and build throughout his or her career.

This continuum of teacher development would define the science and/or mathematics content as well as pedagogical content knowledge teachers need and would suggest the points along a teacher's career path where such knowledge should be developed and how. As teachers grew along this continuum of learning and developed their understanding, they also would enhance and broaden their instructional and assessment repertoires to reflect their own deepening knowledge of content and of children's thinking and learning. It is this type of focused, coherent, and progressive teacher learning that is envisioned by national standards documents to support improved learning by all students of science and mathematics.

For there to be a continuum of professional development that prepares, nurtures, and supports science and mathematics teachers throughout their careers, attention must be focused at several places in the teacher education enterprise. The study described in this monograph uncovered a number of issues that are contributing to the lack of quality both within the preservice and inservice experience of K-12 teachers of science and mathematics and to a lack of coherence in these experiences. These issues range from a lack of shared vision among principal providers of preservice and inservice teacher education, entrenched and isolated roles and responsibilities for teacher development, cultural differences, including between the providers and receivers of teacher development, and lack of coordination among mechanisms for quality control of teaching.

These concerns and barriers identified in the course of the study were discussed in the "Issues" section of this monograph. The "Mechanisms" section of this monograph went on to show how some of these issues and questions are being addressed. Most of the issues identified and questions raised by the study await further research.

Contributors to the study recommend that further research identify the strategies that would begin to create the conditions needed to support teacher learning and to bring about a focused, coherent, and progressive continuum of career-long teacher education. This research should focus on locating and describing promising strategies for connecting preservice and inservice education and for building the culture and structures for career-long professional development of teachers. Specific research recommendations as well as policy and practice recommendations made by the expert group assembled in Phase 3 of this study are as follows.

Recommendation: Educational researchers need to conduct further research on questions raised by this study for which no or incomplete mechanisms were found, including:

- Identify exemplars of how university schedules and school days have been reconfigured to allow time and resources for teacher reflection and career-long learning.

- Provide examples of community college/university cooperation in the preparation of prospective teachers.

- Conduct research and development on how the seven identified barriers to improvement within preservice and inservice teacher education are best addressed.

- Through research, describe in detail the nature of teacher knowledge and skills needed at each point along the developmental continuum, clarifying the ways in which they are qualitatively and quantitatively different.

- Conduct research and development on teacher assessment to make it possible to identify where a teacher is against where she/he needs to be at each stage of teacher development

Recommendation: Administrators in higher education and school districts and state policymakers need to change reward and incentive systems to support teachers to engage in career-long learning and preservice and inservice educators to design and provide quality, coherent learning experiences for teachers.

- State policymakers should revise policies requiring professional development and continuing education credits to ensure that such credit is earned throughout the teaching career.

- Teachers should have a working professional development plan that is updated regularly. Schools should provide support and resources to help teachers meet the objectives in their plan and recognize and reward them for reaching milestones.

- States and localities should develop consistent standards for teacher certification and teacher assessment.

- Schools and institutions of higher education must legitimize time for collaboration and learning by counting it in scheduled time.

- States and school districts should provide clear guidelines and expectations with respect to the essential science and mathematics knowledge desired for prospective and accomplished elementary and secondary school teachers.

- School districts should provide new teachers with longer apprenticeships, a supportive teaching mentor, and lighter teaching loads.

- School district should review and strengthen guidelines for the placement of beginning teachers and teachers teaching outside of their certification areas.

Recommendation: Preservice and inservice educators must build new relationships, capacity, and learning communities.

- Create statewide or regional networks of schools and universities to develop a common vision or understanding of what a focused, coherent, progressive continuum of teacher education looks like and how preservice and inservice educators contribute to enacting it.

- Higher education faculty and professional developers should share examples of their effective practices through databases and electronic and in-person networks.

- Inservice and preservice courses should be tailored to meet the needs of teachers at different points in their careers and identify the best ways for beginning, novice, and experienced teachers to learn from one another.

Recommendation: Create a shared vision and build public support for career-long teacher learning.

- State and local policymakers should build the public's understanding of the complexity of teaching in reformed ways and what it takes (time and effort) to become an accomplished teacher.

- Higher education faculty, school administrators, teachers, and key members of the public should develop and share widely a vision of what reformed teaching looks like and the learning experiences teachers should have to enact it.

There is a remarkable number of "pockets of innovation" working in many parts of the country to build and support a continuum of teacher development. This study has illuminated some issues that need to be addressed and some directions that, if taken, could cause the vision of a coherent, coordinated system to be an important part of every teacher's career in the profession.

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Greater New Orleans Collaborative
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Kansas State University
Los Angeles Collaborative for Teacher Excellence
Louisiana Collaborative for Excellence in the Preparation of Teachers
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Appendix B

Mechanisms for Building a Continuum of Professional Learning Experiences for Teachers of Science and Mathematics

Initiatives	Shared Vision	Communication & Collaboration	Redesigned Clinical Settings	New Materials	Certification and Assessment	Reformulated Rewards/ Incentives	Faculty Development	Leadership	Resources
1. Innovative teacher education program with 5th year internship and science study group (Michigan State University/Averill Elementary School)	√	√	√				√		√
2. Supporting mathematics teacher development with narrative cases (Univ. of Pittsburgh)	√			√					
3. University of Northern Colorado's K-12 preservice program		√	√						
4. University of Northern Iowa's middle grades teacher graduate program	√	√	√						
5. Columbus Regional Mathematics Collaborative Program Columbus (GA) State University	√	√	√						√
6. West Genesee and Syracuse University Teaching Center	√	√	√				√	√	
7. Statewide K-12 and post-secondary teacher development programs (Louisiana)	√	√	√		√		√	√	√

Initiatives	Shared Vision	Communication & Collaboration	Redesigned Clinical Settings	New Materials	Certification and Assessment	Reformulated Rewards/ Incentives	Faculty Development	Leadership	Resources
8. Statewide K-16 education reform initiative – Sci/MathMN (Minnesota)	√	√		√	√	√	√	√	√
9. Salish I Consortium Research Project (Univ. of Iowa)	√	√	√						
10. Creation of Collaborative Professional Development Schools (Kansas State University and three Kansas school districts)	√	√	√			√		√	

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