T•r•a•n•s
TEACHER EDUCATION
F•o•r•m•i•n•g

A Minnesota FRAMEWORK for Mathematics and Science

Developed by

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SCIMATHmn
A policy document

“Education in an academic discipline is no education at all if the student is not put to the intellectual labor of representing the discipline in lucid explanations, apt metaphors, and enlightening graphics; connecting the facts of the discipline to its underlying principles and to other bodies of knowledge; and applying the discipline to situations in life. Not only does such an education fail to serve future teachers, it fails all other students as well.”

(Tyson, 1994)

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Input into this document was provided by over 200 Minnesotans who attended Transforming Teacher Education conferences in 1994 and 1995. The document reflects comments and suggestions offered by the participants from these conferences, along with those who met again in July 1995 to critique the final document.

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PREFACE

> ***"To begin the process of transforming teacher education in mathematics and science so that teachers will be prepared to teach according to the vision of present and future national standards and will be prepared to continue learning new content and new ways of teaching throughout their professional lives..."***

This document offers a vision for what teacher education could be. It is intended as a guide for Minnesota post-secondary institutions as they consider the implications of national and state K–12 reform recommendations for teacher education programs.

SciMath^{MN} is a public/private partnership founded in 1993 with a two-fold mission:

1. To be an advocate for standards-based, systemic reform for Minnesota's science and mathematics education system; and
2. To be a catalyst for implementation in Minnesota of the mathematics standards developed by the National Council of Teachers of Mathematics (NCTM), and of the science standards developed by the National Research Council (NRC).

To accomplish its mission, SciMath^{MN} uses state legislative appropriations and private-sector funds to conduct initiatives in three broad programmatic areas:
policy (changing state education policies to align with the vision of mathematics and science education in the national curriculum standards); ***public awareness*** (raising awareness of and support for standards-based reforms in mathematics and science education); and ***professional development*** (strengthening the preparation of new teachers and the continuing professional growth of practicing teachers in ways consistent with national mathematics and science standards).

In the areas of professional development, SciMath^{MN} has launched several major statewide initiatives. To focus on issues related to pre–service preparation of mathematics and science teachers, SciMath^{MN} organized a critique and consensus process which produced the following document. The document is thus the primary manifestation of the SciMath^{MN} Transforming Teacher Education Initiative.

SciMath^{MN} offers this document to the many stakeholders of Minnesota's teacher education programs, including not only institutions which are direct providers of teacher preparation courses, but also the K–12 constituencies of teachers, administrators, and policymakers as well as government, business, and community organizations interested in these issues.

Our hope is that this document will help engender and focus continuing dialog and consensus building around this emerging vision for teacher education in mathematics and science in Minnesota.

Bill Linder-Scholer
Director of SciMath^{MN}

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Introduction

Transforming Teacher Education

A MINNESOTA FRAMEWORK FOR MATHEMATICS AND SCIENCE

"More is expected of our teaching force now than ever before. Successful efforts to restructure schools for the demands of a knowledge-based economy depend critically on the nation's teachers."

(INTASC, 1995)

This document advocates a Minnesota vision for transforming teacher education in mathematics and science. In this vision:

Beginning mathematics and science teachers will be prepared to teach according to the vision of present and future national Standards, and they will be prepared to continue learning new content and new ways of teaching throughout their professional lives.

It is important to note that a vision is a picture of the future lying just beyond the grasp of today's reality. A shared vision is necessary to provide all stakeholders with a clear picture of the direction for change. Realizing the vision will require imagination and creativity on the part of those involved in the process, and a recognition that not all institutions will attain the vision in the same way. Alternative methods are necessary to achieve the vision in light of the differing needs, realities, and goals of Minnesota teacher education institutions.

Creation of the Document

This document is a response to national ***Standards*** for mathematics and science education, as well as to the emerging Minnesota Graduation Standards for K–12 students and pending changes in Minnesota's teacher licensure system. It is a product of SciMath^{MN} through its Transforming Teacher Education Initiative. This is a first attempt to delineate the Minnesota vision. It is important to note that the sense of the vision will evolve over time as the needs of beginning teachers change.

The ideas presented were drawn from three distinct sources. Initial input was provided by Minnesotans directly involved in K–16 mathematics and science education who attended several state-wide meetings to determine the knowledge and skills needed by teachers of mathematics and science. Additional information was gathered through a review of the existing research literature related to student learning, effective teaching, and teacher education. The final information source involved the analysis and synthesis of national and state ***Standards*** for mathematics and science education, along with other reports providing recommendations for teacher education. Throughout the evolution of the document, the ideas presented were reviewed and evaluated by stakeholders in teacher education.

Purpose of the Document

The purpose of this document is to:

1. Stimulate and inform state dialogue among all stakeholders of teacher education;
2. Guide Minnesota institutions of higher education as they consider their roles and responsibilities in mathematics and science education reform; and,
3. Inform the development and implementation of state licensure rules for teachers of mathematics and science.

The resulting document is intended as a tool for discussions of what teacher education programs in Minnesota could be. It is not a checklist of mandates.

Audience for the Document

This document is intended for distribution to and discussion among all individuals involved in planning and providing the education of K–12 mathematics and science teachers. This list includes students involved in teacher education programs; faculty in mathematics, science, and education departments; field experience supervisors and cooperating teachers; university and K–12 mentors; leaders of professional organizations in mathematics and science; university and school administrators; and representatives from business, industry, government, and funding agencies.

Overview of the Document

The four chapters in this document describe recent reform initiatives in mathematics and science education, delineate the vision for transforming teacher education in Minnesota, make recommendations for systemic change, and discuss the steps necessary to transform teacher education policy into practice.

CHAPTER 1 sets the context for the document by describing the current status of science and mathematics education and presenting a vision for the future. It outlines the background of recent and emerging national ***Standards*** for curriculum, instruction, and teacher education in K–12 mathematics and science, and identifies the special conditions affecting mathematics and science education in Minnesota. Chapter 1 concludes with a scenario that presents an imaginary university which has aligned itself with national and state ***Standards***.

CHAPTER 2 presents a framework for the Minnesota vision. It summarizes and synthesizes standards for beginning teachers' knowledge and skills, and describes experiences that enable them to acquire those skills and knowledge. It then lists necessary roles and responsibilities of faculty involved in all aspects of mathematics and science teacher education, along with characteristics of institutions that produce accomplished beginning teachers.

CHAPTER 3 describes the support needed by Minnesota teacher education programs to effect the transformation of teacher education in mathematics and science. It provides recommendations for various stakeholders in teacher education including faculty, institutions, Minnesotans, government, business, industry, professional organizations, K–12 schools, and school districts.

CHAPTER 4 discusses the challenges to be met if Minnesota is to transform the policy presented in this document into practice. It provides an organizer for use in examining the process of reform, and presents a call for action to all of those involved in teacher education.

Scope of the Document

Changing the knowledge base for mathematics and science teachers requires two concurrent efforts: reform in the education of beginning teachers, and reform in the professional development of current teachers. However, the vision and framework presented in this document focus only on the education of beginning teachers of mathematics and science, leaving the continuing education and professional development of current teachers to future initiatives.

This document refrains from making recom-mendations to institutions regarding the content of specific courses, majors, or programs. Instead, it

provides a resource with which institutions of higher education can examine their teacher education programs,
and develop specific plans to revitalize them. These plans must include consideration of each institution's unique identity, its mission and goals for teacher education, and the specific needs of its students.

This document does not attempt to address all aspects of teacher education. Its focus is on those aspects that are unique to mathematics and science or that are addressed in national and state ***Standards*** for these disciplines. Other equally necessary, but more general, aspects of teacher education are not included.

Assumptions of the Document

This document is built upon the following assumptions:

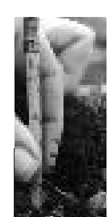
1. A teacher is a decision-making professional who can recognize and generate options when faced with problems.
2. Teachers are the key to effecting mathe-matics and science literacy for all students.
3. The education of mathematics and science teachers is the responsibility of the entire institution.
4. Successful transformation of teacher education requires strong and sustained support from all stakeholders.
5. Effective K–12 teaching requires a continuum of professional development experiences that allow mathematics and science teachers to continue learning throughout their career.
6. Successful efforts to transform the education of mathematics and science teachers will enhance the education of
every student enrolled in an institution's mathematics or science class.
7. All students in mathematics or science classes are potential teachers.

Terms Used in Special Ways in this Document

This document makes careful use of words and phrases that may have different meanings to various members of the teacher education
community. In particular, note the following definitions:

ACCOMPLISHED TEACHERS: Those who have expertise and skills, appropriate for their level of experience, that enable them to teach according to the vision of national and state ***Standards.***

BEGINNING TEACHERS: Those whose level of experience appears somewhere on a continuum from entry into student teaching through their first years of teaching. The distinction between beginning and advanced teachers is not in the types of knowledge and skills they possess, but rather in the degree of



sophistication they exhibit in the application of those skills and knowledge (INTASC,1995).

DISCIPLINE: The subject area of a teacher's expertise. In the case of non-specialist elementary and middle school teachers, this means a broad knowledge of mathematics and the sciences. In the case of secondary teachers, the term discipline refers to a deep under-standing of whatever subject(s) they will be teaching, typically mathematics or one or more of the sciences, combined with a broad view of mathematics and science as related disciplines.

INSTITUTION: A college or university that educates teachers of mathematics and science.

STANDARDS, NATIONAL: The aggregate of recommendations by national mathematics, science, and/or teacher education professional organizations for curriculum, instruction, assessment, and the education of teachers in mathematics and science. An annotated list of the ***Standards*** documents synthesized here appears in Appendices A and B.

STANDARDS, STATE: ***Minnesota's Graduation Standards,*** particularly the ***Profile of Learning,*** which includes content standards for mathematics and science. This document references the June 1995 draft of the ***Profile of Learning.***

STUDENTS, ALL: Every K–12 student, regardless of ability, career goal, gender, ethnicity, or socio-economic status, who is enrolled in a mathematics or science class.

TEACHERS OF MATHEMATICS AND SCIENCE: All teachers who assume responsibility for the mathematics and/or science development of children in grades K–12.

Chapter 1

Context
for Change

A CALL FOR CHANGE

"The reform of teacher education can be considered only in relation to some vision of what it ought to be. ...The yardstick is whether the children taught by graduates of teacher education programs can understand as well as memorize, apply as well as state, imagine as well as copy, solve problems rather than shrug them off, and make themselves felt in a society that seems to be in trouble for lack of these capacities."

(TYSON, 1994)

As we enter the last half decade of the 20th-century, the call for change in school mathematics and science is clear and pervasive. A call for mathematical and scientific literacy for all has been a common message in almost every report that describes the status of our current education system, and the needs of students who will be successful in the future. In order to achieve the intent of this message, nearly every major professional organization in mathematics and science has published new standards which call for reform in three critical dimensions of mathematics and science education: curriculum, instruction, and teachers' knowledge. Reform in these three dimensions requires a concurrent change in teacher education programs.

Changing Curriculum

K–12 curriculum, the first dimension, describes what should be taught in mathematics and science classrooms.

In describing curriculum, reports agree that it is not possible to teach all that is known about either mathematics or science. Instead, deep knowledge of fewer topics is required for literacy with an emphasis on deep understanding of the major themes of the discipline. An important part of this deep under-standing involves making connections between the discipline and the world beyond the classroom. Skills for exploring new problems and meeting the challenges of the future are also emphasized. Curriculum materials focus on the dynamic nature of the disciplines, and the role of technology in learning and doing mathematics and science.

Changing Instruction

The process of K–12 instruction, how content is taught and assessed, is the second important dimension of reform. Influenced by research on cognition, national ***Standards*** emphasize that how the content is taught is at least as important as what content is taught. If students are to view mathematics and science as an integrated whole instead of a fragmented collection of arbitrary topics, the study of mathematics and science should be consistent with the nature of inquiry in the discipline. Instruction must stress student actions such as exploring, investigating, discussing, analyzing, constructing, hypothesizing, and validating. Rather than focusing on memorization and competition, instruction according to the ***Standards*** encourages students to question and think creatively, often as part of a team, about solutions to problems of personal interest or importance to the discipline. Teachers must structure learning so that students can learn habits for inquiry and problem solving at the same time as they develop personal knowledge of the discipline.

Changing Teachers' Knowledge

The substantive changes called for in K–12 mathematics and science curriculum and instruction require concomitant changes in the knowledge base needed by teachers. This is the third critical dimension of mathematics and science education reform. In order to guide students in active inquiry and discovery, teachers must possess a deeper understanding than ever before in four areas: knowledge of their discipline, knowledge of pedagogy, know-ledge of students as learners, and knowledge of the learning and teaching environments in which they will work. In addition, teachers must also understand the nature of quality professional development opportunities, and possess dispositions for continuing professional growth and development.

Changing Teacher Education Programs

To achieve the necessary teacher knowledge base requires a new look at the education of beginning teachers of mathematics and science and their continuing professional development. Minnesota is currently developing a new teacher licensure system that emphasizes teachers' knowledge and competencies instead of the present course-based system. Both national and state changes challenge Minnesota higher education institutions to transform their teacher education programs. By aligning teacher education programs with state and national ***Standards***, colleges and universities can take advantage of the opportunity to affect meaningful reform in K–12 mathematics and science.

This framework provides a tool with which teacher education institutions may examine and renew their programs. To set the stage for the process, this chapter contrasts the old paradigm of mathematics and science education with the new vision presented by the ***Standards.***

The Old Paradigm

Prior to the 80's, school mathematics and science education in the United States and in Minnesota primarily prepared students to function effectively in the social and political climate of the time. Most students learned "shopkeeper" arithmetic and "encyclopedic" or "survey" science. Advanced mathematics and science students learned, in rote fashion, the content that would prepare them for college courses. Mathematics and science were taught as a series of facts, terms, formulas, and procedures with few connections. Neither mathematics or science used extensive problem solving nor decision-making. Science courses might include a few laboratory experiences, but even these experiences only gave students practice in verifying information the instructor or the textbook had already presented.

In mathematics and science courses, as in all other school subjects, students "learned" by watching and listening, copying and drilling. Some students, who were considered "good at" mathematics or science, were encouraged to take more courses on topics of special interest. Others were tracked into "low-ability" groups or courses with uninteresting material and low expectations. Only college-bound students took more than one year of mathematics or science in high school, and only the future science or mathematics majors took trigonometry, chemistry, physics, or advanced biology.

The role of the teacher was prescribed by the curriculum and the "ability level" of the class. Teachers of mathematics and science, at all grade levels, were expected to transmit an established body of knowledge to a homogeneous and passive audience. Lesson planning consisted primarily of making the textbook content palatable to the students, selecting worksheets, and deciding how much homework to assign. High school and junior high school science teachers were also responsible for selecting demonstrations or experiments to illustrate the principles being taught. Teachers had to be masters of the material they covered, but not much else.

Elementary teachers were expected to teach mathematics and science to their students even though most had only a year or two of high school mathematics or science and no college coursework in either discipline.

A brief flurry of reform in mathematics and science during the 1960's produced meaningful curriculum with goals related to the structure of the disciplines and their processes of inquiry. The teacher was still viewed as the authority, and as a result professional development programs for teachers often focused largely on enhancing content knowledge. High school mathematics and science teachers had many opportunities to attend National Science Foundation (NSF) summer and year-long institutes on advanced concepts in their discipline. But these NSF institutes paid little or no attention to the knowledge and skills teachers needed to translate a teacher's personal knowledge into enhanced student understanding. New curricula were developed for students in the elementary grades, but elementary teachers were given little help in implementing new curricula, and most schools provided minimal budgets for supplies. Despite the efforts of these programs, an extensive study of teaching conditions published in 1981 still found three conditions to be most evident: the textbook was the basis for instruction, the teacher determined the tone and type of learning experience, and lecture-discussion was the prevalent mode of presentation (Harms and Yager:1981).

Some students were successful under the old paradigm (e.g., the authors and readers of this document). But a great majority were not successful and opted out of mathematics and science as soon as possible. Mathematics and science were considered subjects for the elite, and it was socially acceptable to admit to being "mathematically phobic" or "scientifically illiterate."

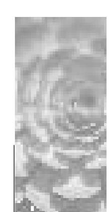
The Need for Change in Mathematics and Science Education

Dissatisfaction with K–12 education resurfaced in the 1980's. Beginning with the release of ***A Nation at Risk*** in 1983, one national report after another decried the current state of American education, particularly in comparison with industrially competitive nations like Japan. At the same time, new research paradigms were generating new theories on how children learned, and new technologies were exploding the available knowledge base and the need for scientifically literate workers. Mathematics and science led the other disciplines in developing national standards or recommendations for school learning.

The term standards, in most of the reform documents, referred to "visions of performance and its associated knowledge and skills" (Richardson:1994:16), not as "goals and their assessments" (Richardson:1994:16), as the term is often used in state graduation or licensure documents.

A catalyst for the new ***Standards*** for K–12 student learning was the realization that the current system was not producing citizens who could compete in the world marketplace. Other factors included:

- New national goals calling for mathematics and science literacy for all, not just for a few mathematicians and scientists.
- Research results that highlight the necessity for new ways of teaching.
- A rapid explosion of knowledge, leading to the realization that fact-based education was no longer possible or sufficient.



- The increasing impact of technology on learning and doing mathematics and science.
- The enhanced role of mathematics and science in everyday life.

In addition, educational policies in Minnesota were also affected by socioeconomic factors. The population of the state has become more urban and culturally diverse. The economy has changed from one with an agricultural and mining base to one focused on growing markets for service, both local and international. Families with a single parent or two working parents are now the norm. The number of children in Minnesota classrooms with special needs has increased, as has the level of stress faced by many children.

New Standards

Since 1989, an abundance of educational reform documents have been published, each referred to as "standards." Both the National Council of Teachers of Mathematics' ***Standards for Curriculum and Assessment in School Mathematics*** and the American Association for the Advancement of Science's ***Project 2061: Science for All Americans*** were released in 1989, followed by documents from many other organizations. Professional mathematics and science organizations that have issued national standards for K–12 curriculum, instruction, and assessment include the American Association for the Advancement of Science (AAAS), the National Council of Teachers of Mathematics (NCTM), the National Research Council (NRC), and the National Science Teachers Association (NSTA).

These same organizations, along with the Mathematical Association of America (MAA), National Board for Professional Teaching Standards (NBOT), and the Interstate New Teacher Assessment and Support Consortium (INTASC) have also issued standards for mathematics and science teaching and teacher education. Together these organizations have created a new vision for students, teachers, and teacher education.

A complete list of these organizations and their reports can be found in Appendices A and B.
A summary of common themes in the reform documents is presented in Table 1.

A New Vision of Students

These documents create a vision of new students and new ways of learning mathematics and science. In this vision, mathematics and science are for all students. These students experiment, inquire, hypothesize, generalize, organize, and evaluate. They solve problems presented by the teacher, but, more importantly, they generate their own questions and problems from personal observations of phenomena. They are familiar with technology and other tools, and know how and when to use them appropriately. They see themselves and their peers as sources of knowledge, and do not rely totally on the teacher to see if what they are doing is "right." They read and communicate orally and in writing about mathematics and science, and they use mathematics and science to understand or explain other parts of the world. They have the confidence and the skills to continue learning, with or without a teacher.

In this new vision of students, mathematics and science are about ideas, not just about procedures. Further, they are about big ideas and connections, not just isolated facts and concepts. Knowing mathematics and science is doing mathematics and science.

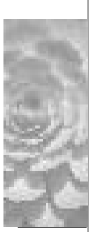
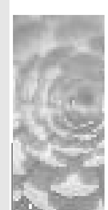


TABLE 1 – COMMON RECOMMENDATIONS OF REFORM DOCUMENTS

STUDENT RECOMMENDATIONS	TEACHER RECOMMENDATIONS
■ Mathematical and scientific literacy for ALL students	■ Teachers as facilitators, catalysts, and coaches
■ Active, hands-on learning	■ Teachers as change agents
■ Critical thinking and problem solving	■ Teacher involvement in decision making
■ In-depth study of fewer topics	■ More team teaching
■ Conceptual learning and understanding	■ Improved teacher preparation
■ Cooperative and collaborative activities	■ Use of exemplary teachers as mentors and role models
■ Connections within and across disciplines	■ Use of multiple types of assessments of teaching
■ Full use of appropriate technology for learning	■ Emphasis on continuing professional development
■ Authentic assessment aligned with instruction	
■ Life-long learning	



A New Vision of Teachers

Teachers in this new vision know the futility of trying to pour knowledge into seemingly empty young heads. Instead, they facilitate and guide their students' learning by helping them to integrate new and previous knowledge.

They serve as coaches and catalysts for learning. They empower their students to become independent learners, to question and evaluate their own and their classmates' conclusions without always referring to the teacher or the textbook for "the truth."

These teachers present information within relevant contexts, rejecting large amounts of drill and the memorization of unconnected facts. They identify, and help students identify, misconceptions that may hamper their learning of new ideas. They make full use of appropriate technology and manipulative models as tools for teaching, learning, and doing mathematics and science. They continually question and rarely tell. They help students learn to work cooperatively, communicate clearly, and reason deeply.

When planning for instruction, teachers identify the big ideas and overarching themes of the content they are teaching, and develop ways to help their students see the connections. They generate multiple strategies to represent the content to accommodate diverse learners and learning styles. They expect to cover less content, but to "uncover" it more deeply. They plan questions and experiences, not lectures. They develop multiple methods to assess students' learning in ways that are authentic to the content and aligned with instruction, and they use assessment results to improve both student learning and their own teaching.

In the new vision, teachers recognize that teaching is a complex practice, not reducible to prescriptions or recipes. They understand mathematics and science as dynamic disciplines, and realize that they must continue to learn about their subject, their students, and instructional strategies throughout their professional lives.

A New Vision of Teacher Education

Teachers of mathematics and science at any level of the K–12 continuum need different knowledge and skills than before to enable them to teach according to the new visions of students and teachers. Thus the national standards imply a new vision for the education of mathematics and science teachers. The remainder of this document describes in detail the vision of teacher education implicit in the national standards and informed by current reform efforts in Minnesota. The scenario which follows describes one possible vision of teacher education.

TEACHER EDUCATION AT RIVERVIEW STATE UNIVERSITY

A Scenario

Riverview State University (RSU) has a national reputation for teacher education. One of the reasons for the institution's quality reputation is its continuing emphasis on evaluation and renovation of programs to ensure that its graduates are prepared to teach not just in Minnesota's schools of today, but also the schools of tomorrow. The university demonstrated this commitment to quality teacher education by being one of the first institutions in Minnesota to join Project Renaissance, a national association of liberal arts and undergraduate institutions committed to exemplary programs for teacher education. Effective teaching at all levels is the number one goal of the institution.

The largely rural area in which the university is located is just now beginning to develop the ethnic diversity that is common in most college communities of comparable size. The university community is more diverse than it once was, partially due to the changing demographics of the state and also as a result of an intensive recruiting program undertaken by the university. The university has worked to increase the diversity of its student and faculty community to more clearly reflect the demographics of the areas in which its graduates will work. In teacher education, the university has strengthened its ties to Twin City schools, and now offers a special emphasis for students who want to teach in urban schools.

RSU's success in teacher preparation is also due to its emphasis on collaboration and innovation in teaching throughout the institution. Faculty and administrators from various departments and colleges routinely work in teams for planning and instruction. Their efforts are recognized and rewarded in many ways by the institution. Time is allocated in faculty loads for this collaboration. At promotion and tenure reviews, faculty are recognized for their contributions to enhance teaching in the same manner that others are recognized for their contributions through research and grantsmanship. Risk taking in teaching is also rewarded. Faculty are encouraged to implement new ideas in curriculum, instruction and assessment. The "failure" of a new idea in teaching is seen as an opportunity for professional growth and development. Respect and trust among faculty and administrators across campus is the norm, and they share a common belief that all departments are responsible for the successes and failures of the teachers who graduate from Riverview.

The Teacher Education Program

The resulting program is one in which all participants take pride. Teachers who graduate from Riverview have strong backgrounds in content and pedagogy, extensive opportunities for clinical experience in a variety of settings throughout the program, and continuing support as they begin their first years of teaching. During their first years at RSU, all students complete solid general education courses in science and mathematics that help them develop a conceptual understanding of the nature of the disciplines, focus on general concepts, and build connections between the disciplines and the world at large. Through strong partnerships with local community colleges, transfer students are able to benefit from the same sorts of quality coursework in content and general education courses. Teacher education majors formally enter the program no later than the beginning of the sophomore year. Throughout the rest of their undergraduate program, courses that focus on pedagogy are paired with content courses and actual school experience. Groups of students enter the program and function as cadres over the next three years. Advising is done by a team of faculty who continue to work with students during their first years of teaching. Applied psychology and multicultural education courses still exist, but they are tailored to the disciplines and age levels at which teacher education majors will be working. Similar technology and exemplary curricula are utilized in all courses and in area schools. Faculty share common assumptions about the impact of student diversity on learning. All faculty understand that meaningful learning requires making connections between new and existing knowledge. They have knowledge of the experiences that students receive in their other classes, and are able to make use of this information in helping students reflect on what they are learning and how it might be useful in future teaching.

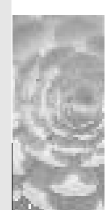
Clinical experiences are a clearly defined part of the teacher education program at Riverview. The courses are taken in a sequence that begins formally in the sophomore year. Students and cooperating teachers receive a list of outcomes to be achieved through their clinical experiences. At first, students work largely with tasks that focus on individuals or small groups, and then as their time and experience in the classroom grows, so does the number and diversity of the students they are assigned to work with. Clinical experiences are always tied to a class in the program, or to the bi-weekly seminars held at the RSU Mathematics and Science Center. The seminars present ideas that link field experience to research on topics such as curriculum and instruction innovations, new assessment techniques, or learning theory. Commonly the audience for a seminar may include discipline-based and education faculty from the university and local schools, students of all ages, and even recent graduates of the program. By the senior year, students have well in excess of 200 hours in the schools even before their actual student teaching experience begins.

A variety of nonformal student experiences also exist. As first-year students, many begin jobs in schools as lunchroom, playground, or instructional aides that they continue to hold throughout their college career. A significant number of junior and senior elementary science and mathematics majors run an afterschool enrichment program in the local school district called School Stop. Other teacher education science and mathematics majors are involved with Scientific Discovery, a series of residential science and mathematics programs that the university runs each summer for under-represented K–12 students.

As seniors, students begin the year in the schools at which they will be student teaching. After participating in beginning-of-the-year activities at the school, they return to campus for a formal science or mathematics methods course in which they work to develop the units they will later teach in the schools. This arrangement gives methods courses greater meaning because students can see the direct application of their efforts. After four weeks on campus, they return to the school and student teach for the rest of the semester. During student teaching, they are observed by faculty from mathematics and science as well as from education departments, and they continue to meet with the on-campus seminar team either in person or electronically.

Student teaching is always scheduled so that the students spend their final semester back on campus. During the last semester, they are involved in a series of capstone courses designed to help them process their experiences and internalize the attitude that teaching science or mathematics involves a life-long commitment to professional development and learning.

Teachers who provide or supervise clinical experiences for Riverview students are identified through an application process. Summer professional development programs for local teachers, the SciMath^{MN} Teacher Academy, and the Department of Children, Families and Learning Best Practice Networks have helped RSU identify teachers to work with students in field experiences. These teachers complete an introductory course on supervision, and are then given opportunities to



choose the sort of involvement they would like to have based on available positions. The teachers who participate receive free university credit for serving as field supervisors, and many have used these credits to enhance their own professional development.

Exemplary Programs in Mathematics and Science

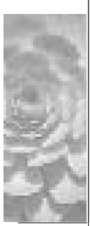
Mathematics and science teacher education at all levels have been especially strong programs at RSU for more than twenty years. These excellent programs benefit from the institution's commitment to quality teaching, but also from the number, diversity, and collaborative efforts of the faculty from both the College of Education and the College of Arts and Sciences. The College of Education has faculty with special expertise in mathematics and science, while each of the mathematics and science departments contain faculty with extensive K–12 classroom teaching experience. These "teaching experts" within the content departments teach special content courses for future teachers, the secondary teaching methods courses, and assist with supervision of student teachers. They also work to enhance the effectiveness of instruction for all students enrolled in the departments' mathematics and science courses. This large cadre of faculty interested in mathematics and science education has made it easier for the university to respond to the challenge of new K–12 state and national standards for science and mathematics education, and the opportunity provided by new state teacher licensure programs.

Resources at the institution are limited and faculty teams have had to be creative in finding ways to fund their innovative programs. Faculty from RSU are active in state and national projects, and this activity has allowed the university to participate in a number of state and federal initiatives. These initiatives have helped Riverview to garner resources in science and mathematics that would not otherwise be available. Federal monies were used by the institution to purchase materials and establish the Mathematics and Science Education Center with two computer laboratories, model classrooms for mathematics and science instruction, and an extensive curriculum resource room. State monies provide many of the resources required to fund professional development opportunities for teachers and summer programs for K–12 students. Private funding has been used to support teaching fellows on campus. These fellows are classroom teachers chosen from local schools throughout the state.

Technology Resources

Interactive TV laboratories in the Mathematics and Science Center allow RSU students to observe school and classroom settings without leaving the university, provide professional development classes for teachers at distant schools, and allow for interactive seminars with students at each professional development site. During their student teaching practicum, students are provided with a lap-top computer and software, access to the Internet for interactions with each other and with the methods classes on campus.

The curriculum and computer resource rooms serve as major sites for the instruction of preservice teachers. In the science and mathematics curriculum room, students have opportunities to evaluate and utilize the latest teaching materials. The room contains complete sets of new curriculum materials along with an extensive collection of print materials including textbooks. Journals focusing both on research and classroom activities which report on current research and recommendations from professional organizations in mathematics and science are also available. Videos and laser discs are available in the curriculum room, while the best software is found in the nearby computer labs. Other available classroom aids include calculators, manipulatives, microscopes, models, telescopes, celestial globes, air track tables, and almost any other tool (from a rock hammer to a dissecting kit) that students might need in



a well-equipped science or mathematics classroom.

The computer classrooms are equally well equipped. Each room has a complete set of 24 computers available with Internet access and CD Rom. Exemplary instructional software is available at all grade levels in both mathematics and science, along with software packages for word processing, spreadsheets, and graphing. Teacher tool kits that include grade programs and classroom organizers are also located here. Probeware is available for use in both the mathematics and science labs, and students can learn to utilize these tools in either the elementary or secondary Mathematics, Science, and Technology courses. It is in these classes that they also get an opportunity to use HyperCard to build stacks for lessons which include real time data as well as images taken from the Internet or laser discs.

As with all RSU students, mathematics and science education majors have a basic familiarity with the computer. They are required to take an introduction to computing course that covers Internet, word pro-cessing, spreadsheets, and graphing programs.

They use the computer to collect and analyze data in mathematics and science content courses and perform library searches. This means that the technology courses in teacher education have finally reached the point at which they can be used to focus on appropriate use of technology for instruction rather than learning basic skills.

The curriculum and computer room supervisors are local teachers on leave from their schools. They are serving this year as Riverview Eisenhower fellows. As a part of their jobs, each semester they team teach one course for preservice teachers with an

RSU faculty. They are each a part of a seminar team presenting special topics in science and/or mathe-matics education, and they spend the remainder of their time in the curriculum or computer rooms. This time gives them an opportunity to learn about new curriculum, and also provides a strong resource for preservice teachers.

The Process of Change

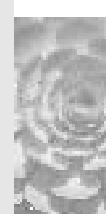
Changes in programs and courses at the university did not take place overnight. Through the years, barriers had been established between the university and local schools, as well as between faculty in the various colleges and departments. It seemed that conversations between various stakeholders in teacher education more often focused on placing blame than on discussing the needs of students and collaboration.

The first steps toward reform involved extensive dialogues among University planning teams to develop a shared vision of what teacher education graduates should know and be able to do, as well

as the roles and responsibilities of each group in achieving this goal. This process was an important first step in re-establishing trust and respect among all of those involved. During this discussion, each group's contributions and needs were uncovered. Education faculty were able to provide important information about educational research and the application of various methodologies and curriculum, but they needed help in understanding the prior knowledge base of university students in the disciplines. Mathematics and science faculty could provide this information, and they were also able to identify those concepts which are most difficult for students. What many of them lacked was knowledge of present day school environments. Classroom teachers provided this knowledge, but needed help to understand how the structure and constraints of the university could challenge the implementation of ideas that would enhance the quality of RSU graduates. Background knowledge and current experience with new reform documents varied widely among individuals in each of these groups. Administrators served as important facilitators of the entire process by providing support and stimulus as needed.

Connections with Schools

RSU currently has strong connections with the surrounding region's elementary, middle, and high schools. A number of years ago the university became a founding partner of their locally developed Coalition for Better Science and



Mathematics Education. This program established partnerships between the university, local schools, and business in an attempt to improve student achievement from kindergarten through college by all studying mathematics and science.

Coalition members make decisions based on the premise that education is a continuum from preschool through university, and that improvement in one part of the system is not possible without improvement in all parts. The purpose of the partnerships then is to enable all members of the Coalition to reform both preservice and inservice teacher education while simultaneously reforming local schools. All partners share a common goal of producing students and teachers who are life-long learners willing and able to utilize mathematical and scientific knowledge and skills in daily life.

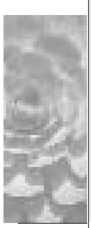
The Coalition began the process of change at the K–12 level by examining emerging state and national recommendations for quality science and mathematics education, and the research related to effective teaching and learning. They examined existing programs and the needs of local students, and used this information to revise student outcomes in science and mathematics. Then teams of university faculty, local teachers, and community members joined to examine exemplary programs in school science and mathematics. They also examined and evaluated curriculum resources for adoption by the local schools. During the next few years, business worked with the schools and university to help acquire the technology and curricular resources needed to implement the new programs. The university made a commitment to obtain similar materials, and incorporate them as appropriate into existing university courses, to promote a seamless transition for preservice and inservice teachers who enrolled in local courses and then worked in area schools. Business helped by identifying local sites to provide teacher and student intern programs in addition to their contribution of financial support and personnel. Throughout the process, an exchange program was used to share the expertise of all participants.

University faculty were paired with individual schools, and began to spend two to three days a week in these schools. This not only included the time they spent supervising clinical experiences, but also allowed them to teach classes, provide professional development activities, and work with teachers to bring additional resources into the schools.

In exchange, teachers in mathematics and science became more involved with teacher education programs, and some teachers were given formal appointments at the university. Teacher contributions included supervising clinical experiences, serving as mentor teachers for student teachers, and working with the university's mentoring programs for beginning teachers. They also worked in the university computer and curriculum rooms, and team taught both content and methods courses at the university. The partnerships and shared roles developed in this project continue today.

Change Continues

The Coalition partnerships that were formed to simultaneously renovate the Riverview teacher education program and local K–12 education in mathematics and science continue to examine and refine their successful model. Planning teams are composed of education specialists (science and mathematics educators, and curriculum and instruction generalists), school system practitioners (teachers and administrators), content specialists (scientists and mathematicians), and university students. The planning teams were responsible for developing the initial program requirements, and turning these requirements into preservice courses and clinical field experiences. They continue to oversee the implementation,



ongoing evaluation, and revision of the program. Indeed, at Riverview State University, program improvement is both a reality and a continuing goal.

Chapter 2

Standards

for the Education of Teachers of Mathematics and Science

"The education of teachers consists of all of the life-long experiences, inside and outside of classrooms, that contribute to the knowledge, skills, beliefs, and attitudes that a teacher brings to the teaching situation."

(POETS, 1994)

CHAPTER OVER VIEW

This chapter describes a Minnesota vision for Transforming Teacher Education. It presents standards for what beginning mathematics and science teachers should know and subsequently be able to do. It identifies the experiences which lead to the development of those skills and knowledge, and describes faculty and institutional roles and responsibilities in providing these experiences.

The chapter is divided into five sections:

Section I Knowing Mathematics and Science

Section II Knowing Pedagogy in Mathematics and Science

Section III Knowing Students as Learners of Mathematics and Science

Section IV Establishing an Environment for Learning Mathematics and Science

Section V Developing as a Teacher in Mathematics and Science

Each section is further divided into four subheadings that provide answers to these questions:

A. What must teachers know and be able to do?

B. What experiences should teachers have to develop their knowledge and skills?

C. What are the roles and responsibilities of faculty in helping teachers develop their knowledge and skills?

D. What are the characteristics of institutions that produce accomplished teachers?

Using this Chapter

This chapter is designed to serve as a basis for dialogue among many diverse stakeholders in the teacher education community. With this purpose in mind, it is appropriate to apportion the responsibilities for careful reading of specific sections among several individuals. This reading can then be followed by cooperative interaction and joint planning by all stakeholders at each teacher education institution. Based on the assumption of multiple readers and cooperative discussion, there is some duplication among sections. Content knowledge is an essential component of an individual's preparation as a teacher of science and mathematics. Teachers need a "deep knowledge" of the discipline in order to teach science or mathematics according to the vision of the national and state ***Standards***. Harriet Tyson, the author of ***Who Will Teach the Children?***, describes this knowledge:

"The 'deep knowledge' teachers need most is the ability to answer the 'why' and 'what for' questions that their students ask, in addition to knowing the basics of the field of study. We need teachers, at every level, who recognize and explicitly deal with the obstacles students face as they struggle to understand, articulate, and apply new knowledge."

(Tyson, 1994)

In this section, the "deep knowledge" of mathematics and science required of beginning teachers is organized into seven categories.

Beginning teachers will:

1. Understand the fundamentals of their discipline.
2. Understand the nature of their discipline from a broader perspective.
3. Apply the discipline in their own lives.
4. Interpret the discipline to develop personal meaning.
5. Know the recommendations of national and state Standards for school content in their discipline.
6. Know the major themes and central content of their discipline, as defined for their teaching level, by national Standards.
7. Know the major themes and central content of their discipline, as defined for high school graduation in Minnesota's Graduation Standards.

Fostering a "deep knowledge" for beginning teachers does not necessarily require additional content courses. Instead, institutions must examine what is learned in content courses and the manner in which content is taught. Programs that produce accomplished beginning teachers will provide experiences that allow them to learn the discipline as mathematicians and scientists do, while making connections within a discipline, across disci-plines, and beyond institutions to the world at large. Faculty who support beginning teachers will examine their role in helping teachers develop the knowledge and skills necessary to teach according to the vision of the ***Standards***. Institutions will provide faculty and learners with the kinds of support they need.

A. WHAT MUST TEACHERS KNOW AND BE ABLE TO DO?

Beginning teachers of mathematics and science will:

1. ***Understand the fundamentals of***

"Teachers' comfort with and confidence in their content knowledge influences how and what they teach."

(NCTM, 1991)

their discipline.

a. Know and use the basic facts, concepts, principles, laws, and theories of the discipline.

b. Know and use the skills and processes of scientific inquiry or mathematical reasoning to solve problems.

c. Know and use the tools and techniques of mathematics and science.

d. Be able to locate sources of information on research in mathematics and science.

e. Be aware of reasonable and safe practice in a laboratory setting, and understand the consequences of inappropriate practice.

2. ***Understand the nature of their discipline from a broader perspective.***

a. Make connections across the sciences, between mathematics and science, and connect mathematics and science with other disciplines and technology.

b. Know how the content-specific knowledge of mathematics and science is unique from other disciplines.

c. Know how their discipline relates and applies to the world, and the role of their discipline in social, cultural, and economic development.

d. Understand the dynamic nature of mathematics and science as a result of new discoveries and new technology.

e. Know the history and philosophy of their discipline.

f. Understand the contributions of different cultures toward the growth and development of mathematics and science.

3. Apply the discipline in their own lives.

a. Use scientific and mathematical knowledge as a basis for decision making when dealing with personal needs and societal issues.

b. Develop their own processes, concepts, and techniques for solving problems.

c. Use tools and technology for personal research and learning.

4. Interpret the discipline to develop personal meaning.

a. Communicate effectively in the discipline at different levels of formality and with different audiences.

b. Know and use analogies, illustrations, and examples in their discipline.

c. Know what makes the learning of specific concepts difficult or easy.

d. Know common initial beliefs and alternative theories in their discipline.

e. Know and use multiple ways of representing concepts.

5. Know the recommendations of national and state Standards for school content in their discipline.

6. Know the major themes and central content of their discipline, as defined for their teaching level, by national Standards.

a. Understand the major themes of mathematics: problem solving, reasoning, communication, and mathematical connections.

b. Understand and use number systems and number sense including: mental mathematics, estimation, reasonableness of results, basic number theory, and the role of algorithms and place values.

IN MATHEMATICS

c. Understand geometry concepts including: shape, space, spatial visualization, geometry from synthetic, coordinate, and trans-formational perspectives.

d. Know and use concepts of measurement, especially from the perspective of its historical development.

e. Understand and use key concepts of statistics and probability.

f. Understand functions and the use of variables and their use in the communication and growth of mathematical ideas.

g. Understand algebraic systems and structures.

h. Understand concepts of calculus.

i. Use tools and modeling applications of discrete mathematics.

IN SCIENCE

a. Understand the nature of scientific inquiry, and be able to conduct scientific investi-gations appropriate to their level of teaching.

b. Understand concepts in the physical sciences including: properties of objects and materials; position and motion of objects; light, heat, electricity, and magnetism; properties and changes of properties of matter; motions and forces; transformations of energy; structure of the atom; structure and properties of matter; chemical reactions; conservation of energy and increase in disorder; and interactions of energy and matter.

c. Understand concepts in the life sciences including: characteristics of organisms; life cycles of organisms; organisms and environments; structure and function in living systems; reproduction and heredity; regulation and behavior; populations and ecosystems; diversity and adaptations of organisms; the cell; the molecular basis of heredity; biological evolution; the inter-dependence of organisms; matter, energy, and organization in living systems; and, the nervous system and behavior of organisms.

d. Understand concepts of earth and space science including: properties of Earth materials; objects in the sky; the structure of the Earth system; Earth's history; Earth in the solar system; energy in the Earth system; geochemical cycles; origin and evolution of Earth system; and, origin and evolution of the universe.

e. Understand about science and technology; distinguish between natural and human-made objects; and have abilities of technological design.

f. Understand science in personal and social perspectives including: personal and community health; characteristics of changes in and the growth of populations; types of resources; changes in environments; environmental quality; natural and human-induced hazards; risks and benefits; and science and technology in local, national, and global challenges.

g. Understand science as a human endeavor; the nature of science and scientific knowledge; and the history of science and historical perspectives.

h. Understand the unifying concepts and processes of science including: order and organization; evidence, models, and explanation; change, constancy, and

measurement; evolution and equilibrium; and, form and function.

7. Know the major themes and central content of their discipline, as defined for high school graduates in Minnesota's Graduation Standards.

IN MATHEMATICS

a. Analyze patterns and use concepts of algebra to represent mathematical relationships in a variety of ways to solve problems.

b. Analyze and use discrete structures to represent mathematical relationships in a variety of ways to solve problems.

c. Apply concepts of shape and space to illustrate and describe the physical world and solve problems.

d. Apply concepts of chance and data handling to evaluate and solve problems.

e. Apply mathematical concepts to technological problems and/or the creation of new products.

f. Apply precision measurement instruments and data handling techniques to technical processes.

g. Use mathematical problem solving and reasoning to analyze information when conducting an investigation.

IN SCIENCE

a. Understand the interactions and interdepen-dence of components of biological systems.

b. Understand the concepts, theories, and interactions of chemical structures and the properties of matter.

c. Understand the interactions and interdepen-dence of components of Earth systems.

d. Understand the interactions and interdepen-dence of components of physical systems.

e. Apply decision-making model(s) to issues involving relationships among the individual, the society, the economy, and the environment.

f. Apply knowledge, skills, and tools of techno-logical systems to extend human capabilities while preserving ecological functions.

g. Understand the processes by which scientific hypotheses are formulated and tested.

h. Comprehend and evaluate reports of events or ideas in the context of scientific knowledge.

i. Understand the interactions between social, economic, technological, and/or environ-mental factors, and the occurrence of scientific advances.

j. Analyze decisions regarding personal wellness based on scientific understanding of the human body.

B. WHAT EXPERIENCES SHOULD TEACHERS HAVE TO DEVELOP THEIR KNOWLEDGE AND SKILLS?

Programs which produce beginning teachers of mathematics and science provide experiences for learners to:

1. Learn as mathematicians and scientists do.

a. Actively investigate scientific and mathematical phenomena.

b. Engage in scientific inquiry, mathematical reasoning, and problem solving in laboratory settings with research projects and through examination of research journals.

c. Investigate issues, events, problems, or topics that are significant to the discipline, important to the community, or of personal interest to learners.

d. Reflect on the content and how they are learning it.

e. Engage in significant discourse about mathematics and science.

f. Use materials such as technology, manipula-tives, scientific and mathematical literature, and media when appropriate to solve problems and broaden the scope of inquiry.

g. Locate, evaluate, and use secondary sources of data (i.e., government documents, experts, databases) as sources for inquiry.

h. Participate in classrooms which model reasonable and safe practice, and provide adequate supervision.

i. Participate in classrooms which model alternative strategies for instruction.

2. Make connections within a discipline, across disciplines, and with the world.

a. Determine the central themes of the discipline.

b. Determine the inter-relationships among science, mathematics, technology, and society.

c. Explore examples of the historical development of ideas to understand how information is created.

d. Uncover the dynamic nature of the discipline including how knowledge is generated and substantiated.

e. Compare various knowledge frameworks and ways of thinking about the discipline.

f. Explore multiple perspectives of mathematics and science including controversies within the disciplines, contributions by both males and females, and belief systems of other cultures.

g. Investigate the national and state ***Standards*** in their discipline.

C. WHAT ARE THE ROLES AND RESPONSIBILITIES OF FACULTY IN HELPING TEACHERS DEVELOP THEIR KNOWLEDGE AND SKILLS?

Faculty will:

1. Model effective teaching by using a variety of techniques such as authentic assessment, collaborative learning, and writing.

2. Model scientific inquiry, mathematical reasoning, and problem solving.

3. Encourage and support learners to take risks as they work independently or cooperatively at solving problems.

4. Encourage full participation and continuing study of mathematics and science by all learners.

5. Encourage reflection both on the nature of the content and on the mechanisms used for learning.

6. Include structured opportunities that build on learners' existing knowledge, skills, and beliefs that

help them make sense of new subject matter.

7. ***Remain open to current thinking and research on effective teaching in mathematics and science.***

D. WHAT ARE THE CHARACTERISTICS OF INSTITUTIONS THAT PRODUCE ACCOMPLISHED TEACHERS?

Institutions that produce accomplished teachers:

1. ***Possess a vision of mathematics and science teaching and learning aligned with state and national*** Standards.

2. ***Integrate and coordinate teacher education program components so that understanding can be built over time, reinforced continuously, and practiced in a variety of settings.***

3. ***Focus on content and pedagogy simultaneously, e.g., through team teaching by discipline and pedagogy experts, or by enrolling learners simultaneously in content and teaching methods courses.***

4. ***Foster collaboration and mutual respect among all stakeholders of the program including beginning teachers, parents/ guardians, teacher practioners, teacher educators, administrators, policymakers, business people, scientists, and mathematicians.***

5. ***Assess programs continuously from multiple perspectives using a variety of strategies.***

"Mathematics [and science] pedagogy focuses on ways in which teachers help their students come to understand and be able to do and use mathematics [and science]."

(NCTM, 1991)

Several essential components of pedagogy serve as lenses through which teachers filter their knowledge of the discipline in order to make effective decisions about teaching. Mastery of pedagogy enables teachers to transform content knowledge into powerful and productive learning experiences that are appropriate for diverse groups of students.

In this section, the knowledge base associated with the mastery of pedagogy required of beginning mathematics and science teachers is organized into six categories. Beginning teachers will:

1. Develop a rationale for making decisions about instruction.
2. Know and use instructional resources.
3. Know and use instructional strategies.
4. Know and use strategies to promote discourse and foster a learning community.
5. Know and use means to assess student understanding.
6. Understand and use pedagogical content knowledge.

Pedagogical content knowledge is the integration of a

teacher's subject matter knowledge and pedagogical knowledge. It is
the form of knowledge that sets mathematics and science teachers apart from teachers in other disciplines, and from mathematicians or scientists. It is not the quality or quantity of discipline knowledge that is unique, but rather the teacher's ability to represent topics in the discipline in ways that make those topics comprehensible to others.

To help beginning teachers transform their understanding of discipline knowledge and general pedagogy into pedagogical content knowledge requires that programs provide beginning teachers with a variety of experiences. These experiences in content courses, education courses, and schools must be interconnected
to achieve the vision of national and state ***Standards***. Professionals who support accomp-lished teachers will examine their roles and responsibilities in this transformation process, while institutions provide faculty and learners with the kinds of support they need.

A. WHAT MUST TEACHERS KNOW AND BE ABLE TO DO?

Beginning teachers of mathematics and science will:

1. Develop a rationale for making decisions about instruction.

a. Know national and state ***Standards*** and their recommendations for the discipline(s).

b. Understand and apply current learning theories, especially as they pertain to mathematics and science.

c. Know and apply the research on effective teaching, especially in mathematics and science.

d. Be aware of research in mathematics and science and its impact on teaching.

e. Understand the dynamic nature of mathematics and science as a result of
new discoveries and new technology.

2. Know and use instructional resources.

a. Know and use a variety of professional resources to support content and pedagogy.

b. Select and evaluate appropriate materials according to the purpose of instruction, the content goals, and the needs of students.

c. Use technology and other tools appropriately for teaching and learning.

3. Know and use instructional strategies.

a. Know and use a variety of instructional strategies to meet the diverse needs of students.

> ***"Learning involves making connections between new information and existing systems of knowledge; teaching should facilitate making these connections by helping students to relate new knowledge to knowledge they have already developed."***
>
> (Brown & Borko, 1992)

b. Facilitate higher-level thinking and learning for all students.

c. Understand and use techniques such as writing in the discipline, concept mapping, and journaling to promote learning.

d. Elicit and respond to students' initial beliefs and alternative theories about mathematics and science.

e. Help students build connections between previous experiences and classroom instruction.

f. Know how to create or modify lessons appropriate to the content.

4. Know and use strategies to promote discourse and foster a learning community.

a. Facilitate cooperative learning and orchestrate classroom discourse.

b. Use techniques for classroom management that promote cooperation and mutual respect among students and teachers.

c. Affirm and support full participation and continued study of mathematics and science in ways appropriate for all students.

d. Develop a positive learning environment that fosters a community of learners in mathematics or science.

5. Know and use means to assess student understanding.

a. Design and evaluate assessment tasks that adequately reflect the content being taught.

b. Know multiple techniques for developing, administering, and analyzing assessments that are aligned with instruction.

c. Make decisions about instruction based on the results of a variety of assessment techniques.

d. Be able to communicate assessment results to students, parents/guardians, and the greater community.

6. Understand and use pedagogical content knowledge.

a. Translate key concepts for students by means of multiple representations.

b. Know the most powerful analogies, illustrations, examples, and demonstrations in their discipline.

c. Be able to analyze potential difficulties in the learning of concepts and processes.

d. Know common student initial beliefs and alternative theories in mathematics and science.

B. WHAT EXPERIENCES SHOULD TEACHERS HAVE TO DEVELOP THEIR KNOWLEDGE AND SKILLS?

Programs which produce beginning teachers of mathematics and science provide experiences for learners to:

1. Develop a rationale statement for teaching mathematics and science.

2. Utilize national goals, state, and local mandates as mechanisms to develop a framework of goals for student learning.

3. Read and interpret research on teaching mathematics and science.

4. Locate, select, and evaluate teaching ideas in professional journals.

5. *Observe a variety of exemplary teachers reflecting on the tasks, discourse, environment, and assessments they use.*

6. *Make connections between research on teaching and classroom practice in specific teaching situations.*

7. *Use various techniques such as interviews, journals, and concept maps to understand student thought.*

8. *Select appropriate content and modify curricula to meet the particular interests, knowledge, skills, and experiences of students.*

9. *Critique current instructional materials and resources such as software, textbooks, manipulatives, instructional kits, professional journals, and specialized curricula.*

10. *Develop and evaluate curriculum, instruction, and assessment plans that, when implemented through teaching, embody the spirit of the national* Standards *in mathematics and science.*

11. *Experience a context of professional practice in which discussions about issues of teaching and learning are closely connected with the everyday work of teaching in schools.*

C. WHAT ARE THE ROLES AND RESPONSIBILITIES OF FACULTY IN HELPING TEACHERS DEVELOP THEIR KNOWLEDGE AND SKILLS?

Faculty will:

1. *Illustrate and model effective teaching by using a variety of techniques such as authentic assessment, collaborative learning, and writing.*

2. *Encourage and support learners to take risks as they work both independently or cooperatively.*

3. *Utilize exemplary instructional materials and appropriate technology.*

4. *Encourage reflection on the mechanisms used for teaching and learning.*

5. *Acknowledge learners' developmental needs and build on existing knowledge of content, teaching, and learning.*

D. WHAT ARE THE CHARACTERISTICS OF INSTITUTIONS THAT PRODUCE ACCOMPLISHED TEACHERS?

Institutions that produce accomplished teachers:

1. *Possess a vision of mathematics and science teaching and teacher development aligned with state and national* Standards.

2. *Integrate and coordinate teacher education program components so that a knowledge base can be built over time, reinforced continuously, and put into practice in a variety of settings.*

3. *Focus on content and pedagogy simultaneously, e.g., through team teaching by discipline and pedagogy experts, or by "shadow courses" in which beginning teachers enroll simultaneously in content and teaching methods courses.*

4. Integrate teacher education coursework with opportunities to assume a variety of experiences with K–12 students from the beginning of the teacher education program.

5. Develop collaboration and mutual respect among all stakeholders of the program, including beginning teachers, parents/ guardians, teacher practitioners, teacher educators, administrators, policy-makers, business people, scientists, and mathematicians.

6. Foster partnerships between teacher education faculty and discipline specialists for supervision of field experiences.

7. Assess programs continuously from multiple perspectives using a variety of strategies.

The focus of national and state ***Standards*** on what all students of mathematics and science should know and be able to do places a special emphasis on teachers' understanding of students. The I***nterstate New Teacher Assessment and Support Consortium Standards*** document best describes this emphasis:

"Teachers work to create learning environments in which students' diverse interests, linguistic, cultural, and socio-economic backgrounds and special educational needs are respected, and in which the full participation and continued study of mathematics (and science) by ALL students is encouraged."

(INTASC, 1995)

In this section, the knowledge base associated with knowing students as learners is organized into four categories. Beginning teachers will:

1. Develop a rationale for making decisions about learners.
2. Appreciate students as individuals.
3. Recognize the implications of student diversity on learning.
4. Foster student learning.

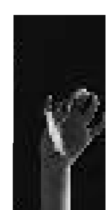
Fostering knowledge of students as learners of mathematics and science may require institutions to change the types of experiences they provide in teacher education programs. Institutions should examine their programs to ensure that experiences with K–12 students begin early and continue throughout the undergraduate teacher education program. These experiences will involve interactions among beginning teachers and university faculty with a diverse range of K–12 students. Faculty involved in all aspects of teacher education will examine their roles and responsibilities in helping beginning teachers learn about students, while institutions provide faculty and learners with the kinds of support they need.

A. WHAT MUST TEACHERS KNOW AND BE ABLE TO DO?

Beginning teachers of mathematics and science will:

1. Develop a rationale for making decisions about learners.

a. Know and apply current national and state ***Standards***-based recommendations for students.



b. Know and apply the research on student learning, especially the learning of mathematics and science.

2. Appreciate students as individuals.

a. Understand that individuals learn in different ways.

b. Understand the principles of human development including characteristics, patterns, and variations of normal physical, emotional, intellectual, behavioral, and social development.

c. Understand that individual students have unique beliefs about the world which influence their interests and expectations.

d. Understand the impact of teachers' beliefs, attitudes, and actions on students.

3. Recognize the implications of student diversity on learning.

a. Know how students' multiple perspectives, due to cognitive and physical development, may affect learning.

b. Know how student diversity (linguistic, ethnic, racial, socio-economic, gender) affects learning.

4. Foster student learning.

a. Know and use a variety of instructional strategies.

b. Know and use a variety of professional resources.

c. Know how to identify and elicit students' beliefs about the discipline.

d. Possess a repertoire of pertinent, culturally relevant examples, analogies, and metaphors.

e. Understand how language acquisition skills are used to teach mathematics or science to students whose primary language is not English.

B. WHAT EXPERIENCES SHOULD TEACHERS HAVE TO DEVELOP THEIR KNOWLEDGE AND SKILLS?

Programs which produce beginning teachers of

"Beginning teachers need to understand that the purpose of the school is the education and development of the whole child."

(TTE Conference, January 1994)

mathematics and science provide experiences for learners to:

1. ***Participate in experiences** with students of various ages and abilities to develop understanding of the differences in individual students.*

2. ***Participate in experiences** with K–12 students that reflect cultural, ethnic, and socio-economic diversity.*

3. ***Use various techniques** such as interviews and concept maps to elicit student beliefs about the discipline.*

4. ***Listen and talk** with students as they construct personal meanings of mathematics and science concepts.*

5. ***Observe an individual student** over time, and analyze the student's thinking and beliefs about mathematics and science.*

6. ***Observe and assist teachers** who work with students from different backgrounds and are effective in the teaching of mathematics and science.*

7. ***Discuss with effective teachers** how they make personal decisions about student learning situations.*

8. ***Read and evaluate research** on student diversity and effective instructional strategies.*

9. ***Discuss mathematics and science education** research, particularly as it applies to diverse student populations, with peers, faculty, teacher practioners, and scientists or mathematicians.*

10. ***Examine state and national*** Standards ***to identify the recommendations they make about students.***

11. ***Select and create** instructional materials that reflect ethnic and cultural inclusion.*

12. ***Identify and practice** various strategies that encourage full and active participation of all students in mathematics and science.*

13. ***Modify the context** of mathematics and science content to better relate it to the lives of students from different backgrounds.*

C. WHAT ARE THE ROLES AND RESPONSIBILITIES OF FACULTY IN HELPING TEACHERS DEVELOP THEIR KNOWLEDGE AND SKILLS?

Faculty will:

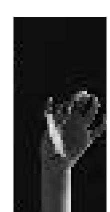
1. ***Design experiences** with K–12 students which align with the vision of state and national* Standards.

2. ***Select appropriate mentor teachers** who can provide valuable learning experiences for beginning teachers.*

3. ***Form professional partnerships** with school faculty who serve as mentors of beginning teachers.*

4. ***Design student teaching** to expand upon previous experiences with K–12 students.*

D. WHAT ARE THE CHARACTERISTICS OF INSTITUTIONS THAT PRODUCE ACCOMPLISHED TEACHERS?



Institutions that produce accomplished teachers:

1. ***Possess a vision of mathematics and science teaching and learning aligned with state and national*** Standards.

2. ***Have diverse faculty and student populations in undergraduate teacher education programs.***

3. ***Foster substantive, professional discussions among discipline-based and professional education faculty.***

4. ***Foster substantive, professional discussion among university and K–12 faculty.***

5. ***Initiate beginning teachers into a professional community of educators (i.e., MSTA, MCTM, MFT, MEA).***

6. ***Provide school experiences that begin early (no later than the sophomore year) and continue throughout the undergraduate teacher education program.***

7. ***Connect school experiences with the development of the knowledge base about students from different backgrounds.***

The knowledge and skills needed to create an emotionally safe and supportive environment were presented in Sections II and III. Another aspect of establishing an environment for learning mathematics and science includes the physical arrangement of the classroom.

Teachers should organize the physical environment of the classroom to ensure that students have the space, resources, and time they need to do science and mathematics. Yet learning environments also extend beyond classroom walls. For teachers to be effective implementors of the ***Standards,*** they must also be able to use community and global resources for instruction.

Establishing safe and supportive learning environments for students requires that teachers also feel safe and supported in their teaching environment. To do this, they need to understand the school and community environments in which they teach. This means being able to use strategies for learning about the culture of the local school and community. Teachers need to understand that effective teaching requires the support of individuals beyond the classroom, including adminis-trators, parents/guardians, school staff, and other faculty.

In this section, the knowledge base needed by beginning teachers of mathematics and science to establish an environment for learning is organized into four categories. Beginning teachers will:

1. Develop a rationale for making decisions about

learning environments.

2. Establish a physical environment for learning.

3. Use community and global resources for instruction.

4. Understand the school/community environment for teaching.

Fostering the knowledge and skills teachers need to establish a safe and supportive learning environment requires that institutions provide experiences for beginning teachers that allow them to acquire greater exposure to schools and other community settings. Institutions must also form partnerships with business and industry to provide the resources necessary to make institutional classrooms and laboratories model sites for safe, accessible mathematics and science teaching.

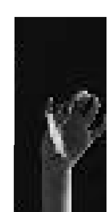
A. WHAT MUST TEACHERS KNOW AND BE ABLE TO DO?

Beginning teachers of mathematics and science will:

1. Develop a rationale for making decisions about learning environments.

a. Know national and state ***Standards*** recommendations for learning environments in their discipline(s).

b. Know the positions of state and national professional organizations on safe learning environments.



c. Know state and national legislation regarding a safe workplace.

2. Establish a physical environment for learning.

a. Know and apply state and national guidelines for use of chemicals, organisms, and equipment in laboratory settings.

b. Know guidelines regarding personal liability in a laboratory setting.

c. Know the liabilities and responsibilities of the administration and school board for a safe laboratory.

d. Know characteristics of laboratory settings that provide students with appropriate access to the tools and materials needed for hands-on mathematics and science.

e. Know features of classrooms organized to meet the needs of students with disabilities.

f. Know safety equipment that must be available in classroom or laboratory settings, and ensure appropriate use.

g. Know procedures for correcting safety deficiencies.

h. Acquire and maintain materials for classroom use such as educational software, instructional kits, and videos.

i. Know of and use alternative settings for instruction.

j. Know of and use professional organizations and publications for decisions about equipment and supplies.

3. Use community and global resources for instruction.

a. Know of important real-world events, problems, and experiences to set contexts and provide learning.

b. Know of traditional and non-traditional sites such as museums, nature centers, and local industry that can be used for formal and informal instruction.

c. Know and use local resources such as speakers and community organizations.

4. Understand the school/community environment for teaching.

a. Know and use strategies to determine what a school expects of teachers.

b. Know and use strategies to determine the demographics (socio-economic, safety, crime, etc.) of the school community.

c. Know how others (administrators, the community, parents/guardians, other teachers, staff, and professional organizations) can impact their

"We believe that professional teachers assume roles that extend beyond the classroom and include responsibilities for connecting to parents and other professionals, developing the school as a learning organization, and using community resources to foster the education and welfare of students."

(INTASC, 1992)

teaching.

d. Know where or how to find the philosophy, mission, and goals of a district.

e. Understand how district goals are determined and assessed.

f. Know how a school system operates.

g. Know how to ask questions and make observations about the political and cultural climates, including community beliefs and attitudes within the school.

h. Understand the central role of state and local politics in funding and policy related to mathematics and science education.

B. WHAT EXPERIENCES SHOULD TEACHERS HAVE TO DEVELOP THEIR KNOWLEDGE AND SKILLS?

Programs which produce beginning teachers of mathematics and science provide experiences for learners to:

1. ***Review national and state*** Standards ***for recommendations regarding a safe and supportive learning environment.***

2. ***Develop model laboratory settings that provide students with appropriate access to the tools and materials needed for hands-on mathematics and science.***

3. ***Examine and evaluate systems for the safe organization and storage of materials needed to do hands-on mathematics and science.***

4. ***Examine various designs for effective classroom and laboratories that meet the needs of all students.***

5. ***Examine catalogs and other resources for materials to teach mathematics and science.***

6. ***Participate in classrooms which model reasonable care and safety, and provide adequate supervision and appropriate use of laboratory safety equipment.***

7. ***Develop a file of community resources for a typical community.***

8. ***Investigate the political and social culture of a school within a community, and its impact on students and learning.***

C. WHAT ARE THE ROLES AND RESPONSIBILITIES OF FACULTY IN HELPING TEACHERS DEVELOP THEIR KNOWLEDGE AND SKILLS?

Faculty will:

1. ***Develop an understanding of current school environments.***

2. ***Develop connections with schools.***

3. Teach in settings that are safe, accessible, and appropriate for instruction.

4. Know the resources of the community and utilize them, as appropriate, for instruction.

D. WHAT ARE THE CHARACTERISTICS OF INSTITUTIONS THAT PRODUCE ACCOMPLISHED TEACHERS?

Institutions that produce accomplished teachers:

1. Possess a vision of mathematics and science teaching and learning aligned with state and national Standards.

2. Center programs in school or other settings that represent real teaching situations.

3. Organize teacher education programs around teachers' experiences, case studies, and artifacts of schooling.

4. Teacher education courses should be taught by faculty with strong K–12 connections.

5. Form collaborations with schools, institutions, and businesses to prepare mathematics and science teachers who can use all the resources of the community.

Professional development is a "life-long" learning process that begins with the first course in a beginning teacher's undergraduate program. As described in this quote, professional development

"... is a dynamic process extending from initial preparation over the course of an entire career. Professional teachers are responsible for planning and pursuing their on-going learning, for reflection with colleagues on their practice, and for contributing to the profession's knowledge base."

(INTASC, 1992)

As an introduction to professional development, teachers need on-going opportunities to observe and talk with master practitioners on a regular basis. They should be introduced to the skills, knowledge, and dispositions they need to engage in life-long learning. This includes the previously defined knowledge base related to content, pedagogy, students, and learning environments along with other professional development topics presented in this section.

In this section, the knowledge base needed by beginning teachers of mathematics and science to begin the process of "life-long learning" is organized into five categories. They are:

1. Develop a rationale for making decisions about professional development.
2. Act as knowledgeable and effective consumers of research as it relates to their teaching and to their students.
3. Understand the nature of professional development.
4. Act as reflective practitioners.

5. Identify and use resources for professional development.

Fostering professional development requires that institutions help each beginning teacher develop as a reflective practitioner, and use this reflection to impact practice. As teachers grow and develop as professionals, they need experiences that begin in teacher preparation institutions, and they need to move into schools that serve as models for effective practice. Faculty and others who support the professional development of teachers must examine their roles and responsibilities in this process. In order to provide a seamless transition between preservice and inservice experiences, institutions must have a vision of mathematics and science teaching aligned with state and national ***Standards***, and provide faculty and learners with the kinds of support they need to be effective.

When reading this section, it is important to note that the professional development of beginning teachers must be shared with other responsible stakeholders, including teacher practioners, K–12 schools, the community, and professional organizations.

A. WHAT MUST TEACHERS KNOW AND BE ABLE TO DO?

Beginning teachers of mathematics and science will:

1. Develop a rationale for making decisions about professional development.

a. Know the recommendations of national and state ***Standards.***

b. Know the recommendations of state and national professional organizations.

c. Know related research.

2. Act as knowledgeable and effective consumers of research as it relates to their teaching and students.

3. Understand the nature of professional

development.

a. Understand that learning mathematics and science is a career-long process.

b. Know that becoming an effective teacher of mathematics and science is a continuous process that stretches to retirement.

c. Understand the role of a learning community in professional growth and development.

d. Understand the teacher's role in changing school culture and practice.

e. Understand the benefits and opportunities of memberships in mathematics and science teachers' organizations.

4. Act as reflective practitioners.

a. Use tools for reflection including journals, audio tapes, videotapes, and portfolios.

b. Conduct investigations into the effectiveness of their teaching.

5. Identify and use resources for professional development.

a. Identify and evaluate the usefulness of popular and professional literature in mathematics, science, and education.

b. Develop and utilize professional networks of colleagues.

c. Use communication technology to access and assure continuing professional development.

d. Locate opportunities (workshops, conferences, and courses) for professional development in mathematics, science, and education.

B. WHAT EXPERIENCES SHOULD TEACHERS HAVE TO DEVELOP THEIR KNOWLEDGE AND SKILLS?

Programs which produce beginning teachers of mathematics and science provide experiences for learners to:

1. Review national and state Standards ***for recommendations regarding professional growth and development.***

2. Reflect on learning and teaching individually and with colleagues at various stages of professional development.

3. Begin and sustain interaction with master practitioners such as mentors, teacher advisors, coaches, lead teachers, and resource teachers.

4. Explore alternative instructional strategies, and receive feedback about their teaching.

5. Read, react to, and discuss professional publications in mathematics and science education.

6. Participate in electronic networks focused on mathematics and science teaching.

"Professional development ideally leads to exemplary teachers who, in partnership with others in the school and community, have a good command of their subject matter, and have the pedagogical skills necessary to create productive learning environments for diverse populations of students."

(HART, ET. AL., 1994)

7. Participate in state or regional meetings of professional mathematics and science organizations.

8. Become involved with professional organizations in mathematics and science education.

9. Participate in personal reflections on the teacher education program at their institution.

C. WHAT ARE THE ROLES AND RESPONSIBILITIES OF FACULTY IN HELPING TEACHERS DEVELOP THEIR KNOWLEDGE AND SKILLS?

Faculty will:

1. Serve as strong models for professional growth and development. This includes faculty from the institution and at field sites.

2. Participate in scholarly and professional activities related to effective teaching.

3. Model service to professional organizations. This includes both discipline-based and professional teaching faculty.

D. WHAT ARE THE CHARACTERISTICS OF INSTITUTIONS THAT PRODUCE ACCOMPLISHED TEACHERS?

Institutions that produce accomplished teachers:

1. Possess a vision of mathematics and science teaching and learning aligned with state and national Standards.

2. Consider professional development as a key component of teacher education.

3. Understand the professional develop-ment of beginning teachers as the shared responsibility of the entire education community, including the institution,
teacher practioners, K–12 schools, state education organizations, and professional organizations.

4. Provide professional development opportunities for teachers that clearly and appropriately connect to teachers' work in the context of the school.

5. Ensure alignment between undergraduates and K–12 experiences for beginning teachers by working in partnership with local schools.

6. ***Establish and support** a beginning teacher network for recent graduates.*
7. ***Make institutional resources** available to teachers after graduation.*
8. ***Value and reward faculty** participation in professional development related to effective teaching.*
9. ***Serve as models** for change by continuously evaluating and improving teacher preparation programs.*
10. ***Solicit feedback** from individuals who were part of the institution's teacher education program.*

"The notion of being a 'life-long learner' is not optional in such a profession [mathematics and science teaching]; it is rather an integrated part of the practice of one's art."

MARY PEARLMAN

Chapter 3

Recommendations

for Transforming the Education of Teachers of Mathematics and Science

"Never doubt that a small group of thoughtful, committed individuals can change the world: indeed it is the only thing that ever has."

MARGARET MEAD

INTRODUCTION

The next decade will be a time of excitement and challenge for Minnesota teacher preparation institutions. New discipline knowledge, new technology, and new understanding of teaching and learning will provide institutions with the information they need to address the vision created by state and national ***Standards*** for teacher preparation.

The previous chapter described a framework for achieving Minnesota's vision for accomplished beginning mathematics and science teachers. Standards for teacher experiences were provided to develop the knowledge and skills teachers need to facilitate all K–12 students in the attainment of scientific and mathematical literacy. Descriptions of faculty roles and responsibilities needed to support beginning teachers were also presented, along with characteristics of institutions that produce accomplished beginners.

The next steps require that institutions begin a process of self-assessment. First, teams of teacher education stakeholders at each institution must closely examine the Minnesota vision, underlying state and national ***Standards***, and necessary conditions in Minnesota for teacher licensure. Then, institutions should review their own unique needs, realities, and goals for teacher education. Finally, institutions should examine the align-ment of their own teacher education programs with the vision presented here, and determine where change is necessary and possible in light of the Minnesota rules for teacher licensure.

The recommendations in this chapter relate to the processes of trans-formation, implementation, and continuous renewal of a quality teacher education program. The transformation process is complex. It requires systemic change both within the institution and beyond. Recent research related to systemic change stresses the importance of a shared leadership model in which the unique contributions and efforts of every stakeholder are utilized in the process of reform. The pages which follow define the unique roles and responsibilities of faculty, institutions, Minnesotans, government, business and industry, professional organizations, and K–12 schools/districts.

A. MODEL DEVELOPMENT OF PROFESSIONAL NETWORKS.

Faculty will:

1. Develop sustained connections with

"You cannot be responsible for the outcome, but you are responsible for the effort."

MARY JO COPELAND

K–12 schools and school personnel.

a. Identify mentor teachers who can provide valuable experiences for beginning teachers.

b. Form professional partnerships with K–12 faculty who serve as mentors of beginning teachers.

c. Develop an understanding of the current school culture.

d. Invite school faculty into discipline and professional education departments to serve as resources for teaching, and to help K–12 teachers develop a better understanding of institutional culture.

e. Develop professional connections with school staff, teachers, and administrators at field experience sites.

2. Develop sustained connections with professional teaching organizations.

3. Develop sustained professional connections with faculty in other disciplines.

B. MODEL PROFESSIONAL GROWTH AND DEVELOPMENT.

Faculty will:

1. Understand and apply research on teaching and learning.

2. Participate in scholarly activity.

a. Conduct research related to their discipline.

b. Use action research and other reflective techniques to continually improve their teaching.

3. Maintain an active professional development plan.

a. Continuously update their knowledge and skills.

b. Participate in professional activities related to effective teaching.

4. Contribute to professional (discipline-based and educational) organizations and agencies.

5. Serve as mentors for beginning teachers.

C. MODEL EXEMPLARY TEACHING.

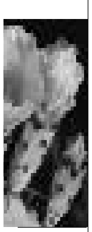
Faculty will:

1. Use active teaching strategies.

a. Utilize strategies for engaging mathematics and science students in active learning.

b. Utilize exemplary instructional materials and appropriate technology.

2. Utilize authentic assessment aligned with instruction.



3. Acknowledge and accommodate learners' developmental needs.

4. Help learners incorporate new ideas into their existing framework.

5. Encourage reflection on the nature of the content, and on the mechanisms used for learning.

6. Provide a supportive atmosphere.

a. Encourage full participation and continuing study of mathematics and science by all learners.

b. Encourage and support learners to take intellectual risks as they work independently or cooperatively.

c. Provide settings that are safe, accessible, and appropriate for learning.

A. MAKE TEACHER EDUCATION A PRIORITY OF THE INSTITUTION.

Institutions will:

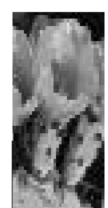
1. View teacher education as a major responsibility to society.

2. Assign highly-qualified faculty to teacher education programs.

B. ALLOCATE RESOURCES IN A DELIBERATE WAY TO SUPPORT

"We teach what we learn and the cycle goes on."

JOAN L. CURCIO



QUALITY IN TEACHER EDUCATION PROGRAMS.

Institutions will:

1. Support faculty who model a professional approach to teaching.

a. Sponsor seminars on such topics as teaching, curriculum, assessment, and technology both within and between departments.

b. Establish department and university support for curricular innovation and quality teaching through the faculty reward system (e.g., salary, promotion, tenure, and load).

2. Support faculty involvement in the schools.

a. Provide resources that allow faculty to spend time in the schools.

b. Provide professional development opportunities for faculty that clearly and appropriately connect to teachers' work in the context of the school.

c. Reward school involvement by faculty as valuable contributions to the life of the institution.

3. Support school involvement in the university.

a. Use K–12 teachers to team teach university courses.

b. Establish K–16 collaboratives.

c. Use K–12 teachers and administrators as advisors for university programs and practice.

4. Provide specialized classrooms and laboratories; state-of-the-art curricular and demonstration materials; and calculators and computer technology at least comparable to those used in the best elementary and secondary schools.

5. Hire faculty and recruit student populations in undergraduate teacher education programs who reflect diversity.

C. ENSURE QUALITY CANDIDATES.

Institutions will:

1. Recruit capable students.

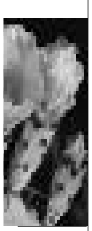
2. Encourage talented mathematics and science students to consider teaching.

3. Maintain high standards for admission to and completion of teacher education programs.

4. Assure that teacher education students develop general literacy and thinking abilities.

D. DEVELOP A STRONG AND INTEGRATED PROGRAM.

Institutions will:



1. Include a quality general education program, an in-depth subject matter preparation, and both general and content-specific preparation in teaching methodology.

2. Develop strong partnerships with other higher education institutions.

3. Integrate and coordinate teacher education program components so that understanding can be built over time, reinforced continuously, and practiced in a variety of settings.

4. Integrate coursework in teacher education with opportunities to assume various classroom responsibilities throughout the teacher education program.

5. Provide realistic teaching experiences.

a. Organize teacher education programs around teachers' experiences, case studies, and artifacts of schooling.

b. Use community resources to complement instruction.

6. Provide opportunities for peer support during student teaching.

7. Provide continuing support to recent graduates.

a. Establish and support a beginning teacher network.

b. Make the resources of the institution available to teachers after graduation.

E. INVOLVE ALL STAKEHOLDERS.

Institutions will:

1. Foster discourse among individuals within the institution and beyond.

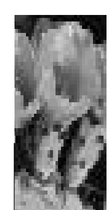
a. Encourage discourse among faculty in mathematics, science, and education; administrators; and teacher practitioners involved in the education of beginning teachers.

b. Form professional communities for discussion among faculty from discipline and education departments, and from school sites.

2. Facilitate beginning teachers initial involvement into a community of professional practice.

3. Develop collaboration and mutual respect among all stakeholders of the program.

a. Foster partnerships among beginning teachers, teacher practitioners, teacher educators, mathematicians and scientists, administrators, policy-makers, and business people for



development of quality programs.

b. Foster partnerships between teacher education faculty, discipline specialists, and teacher practitioners for supervision of field experiences.

c. Foster partnerships between teacher education faculty, discipline specialists, and teacher practitioners for planning and teaching courses.

F. STRESS ACCOUNTABILITY AT ALL LEVELS.

Institutions will:

1. Assess programs continuously from multiple perspectives using a variety of strategies.

2. Make all departments accountable for their contributions to teacher education.

3. Develop equitable methods for evaluating faculty teaching and professional development.

4. Define vigorous learning expectations and exit requirements for all learners.

A. MINNESOTANS SHOULD:

1. Develop and model habits for life-long learning.

2. Value education and quality teaching.

3. Encourage talented individuals to become mathematics and science teachers.

4. Recognize the contribution of quality teacher education programs to the quality of life in Minnesota.

5. Be aware of the existence and importance of state and national Standards**.**

6. Recognize teachers as professionals.

7. Make a commitment to adequately fund teacher education.

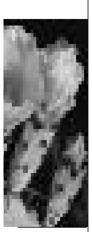
B. GOVERNMENT SHOULD:

1. Recognize that the education of mathematics and science teachers is an investment in Minnesota's future.

2. Recognize that the preparation of

"It takes a whole university to educate a teacher."

ADAPTATION OF AFRICAN PROVERB



quality mathematics and science teachers is a complex process that cannot be accomplished simply by mandate.

3. Develop, fund, and enforce teacher licensure and evaluation guidelines consistent with national Standards.

4. Make a commitment to develop and fund a coherent vision of quality teacher education.

5. Provide significant time and resources to achieve the vision of quality teacher education.

6. Understand that educational reform must be systemic, and cannot be accomplished simply by changing K–12 teachers and schools.

7. Work with university leaders to support effective teacher education programs.

C. BUSINESS AND INDUSTRY SHOULD:

1. Participate in state and local collabor-ations that are working to improve the education of mathematics and science teachers.

2. Communicate the need for mathematically and scientifically literate workers to K–16 educators, administrators, curriculum developers, and faculty.

3. Provide internships for beginning teachers to acquaint them with industry resources for teaching.

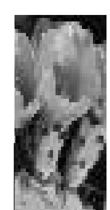
4. Support efforts to secure funds for teacher education.

D. PROFESSIONAL ORGANIZATIONS SHOULD:

1. Form partnerships among K–12 and higher education professional organizations (discipline-based and teaching organizations).

2. Sponsor forums on mathematics and science teacher education that draw stakeholders from diverse constituencies.

3. Maintain on-going dialogue about the needs of beginning mathematics and science teachers.



4. ***Recognize exemplary** beginning teachers and teacher education programs in mathematics and science.*

5. ***Provide opportunities** and encouragement for beginning mathematics and science teachers to participate in conferences and other activities.*

E. K–12 SCHOOLS/DISTRICTS SHOULD:

1. ***Support beginning teachers** through mentoring and appropriate assignments.*

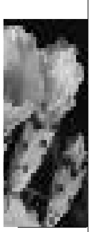
2. ***Encourage and support** professional growth and development.*

3. ***Establish and support** professional networks.*

4. ***Establish partnerships** with teacher education institutions for the continuing professional growth and development of all teachers.*

"America's future walks through the doors of our schools each day."

MARY JEAN LE TENDRE



Chapter 4

Transforming

Policy to Practice

"Efforts to bring about lasting change must proceed steadily for many years, on many levels simultaneously, with the broad involvement of all of the constituencies at each stage."

(NRC, 1989)

THE TIME FOR CHANGE

There has never been a better time in Minnesota to transform teacher education. The ***Minnesota Graduation Standards*** and new K–12 national standards in mathematics and science have piqued public interest in education. New recommendations are currently being made for initial teacher licensure and continuing professional development at both the state and national levels. Emerging research findings on teacher knowledge and teacher education provide direction for reform and new educational technologies provide the tools. In addition, many Minnesota institutions of higher education are now beginning program and curriculum reform as they undergo the change from quarter to semester systems. The shared vision described by this document provides a focus for the transformation of teacher education.

Challenges to Meet

The process of transformation has already begun in Minnesota. Kindled by the process that resulted in this document, widespread dialogues are now occurring across the state between all stake-holders involved in teacher education. But these dialogues are only a first step in the process. Numerous challenges still remain. Many individuals involved in teacher education have strongly held beliefs about how teachers should be prepared. They teach according to these beliefs, they know they are doing a good job, and they see no reason to change. For them, trans-forming teacher education means changing someone else's program.

Existing political frameworks also serve as barriers at both the state and national level. Political decisions are frequently made by committees more concerned about consensus than reform. As a result, the decisions made often do not reflect the intent of state or national reform efforts. Cost and time may be two of the biggest barriers to reform. Both are precious commodities and reform requires a significant commitment of both, often from individuals who have little of either to spare.

Teacher education institutions across the state are at different points in the reform process. Even within a single institution great diversity exists among individuals and departments in their understanding of current recommen-dations for teacher education and in their willingness to change. The strengths and skills of the various stakeholders involved in reform also result in variations of purpose and process. Because of these variations, the process of reform appears to be disjointed.

An Organizer for Reform

The pathway of reform may seem less disjointed if one examines the process through an organizer for reform suggested by Rodger Bybee, Executive Director of the Center for Science, Mathematics, and Engineering Education at the National Research Council. He has identified four stages of the reform process in science education. These four stages, which are equally useful in discussing reform in teacher education, are: clarifying the ***purposes*** of teacher education, establishing ***policies*** for different aspects of teacher education, developing ***programs*** for teacher education, and changing ***practices*** in teacher education classrooms (Bybee, 1995). Applying this model to the Minnesota Transforming Teacher Education process reveals that the first two stages have been achieved.

PURPOSE

The vision of the Transforming Teacher Education Committee defines a ***purpose*** for mathematics and science teacher education in Minnesota. It states that:

Beginning mathematics and science teachers will be prepared to teach according to the vision of present and future national standards, and they will be prepared to continue learning new content and new ways of teaching throughout their professional lives.

POLICY

This document, ***Transforming Teacher Education: A Minnesota Framework for Mathematics and Science***, provides ***policy*** for state efforts to improve teacher education,
in Minnesota. It directs the state's attention toward a common goal for teacher education and provides guidance for institutions as they examine existing programs and make choices for restructuring. It outlines the knowledge, skills, and experiences beginning teachers need in order to teach according to the vision of state and national standards.

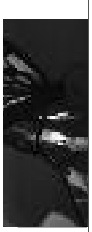
PROGRAM AND PRACTICE

It is the last two stages of Bybee's model that remain to be achieved in Minnesota. Programs are the courses, lessons, tasks, textbooks, experiences, and assessments that are needed to implement stated policy. These will require a great deal of work by many groups and individuals. Furthermore, each component of the programs developed will have to meet
the needs of individual institutions. Finally, practice refers to the individual actions of teacher educators in their own classrooms. Achievement of this component will be the most difficult and time consuming as more people are engaged in the process and as more resources are needed. A variety of individuals will need to dedicate long-term personal commitment to the same idea.

Why Policy is Not Enough

Transforming the policy presented by this document to programs and practice requires an understanding of the reform effort, a commitment to recommendations, and
changes in the behavior and beliefs of individual educators. This framework can
be a powerful tool to begin the process, but
a framework alone is not sufficient to create standards-based systemic reform in teacher education.

Contemporary educational thought provides several reasons why policy alone is not enough to initiate and



sustain educational reform (Fullan: 1993). First, the document may be misunderstood due to the mindset of the reader. Each reader brings a unique perspective to the document, a perspective developed from the experiences he/she has had with teacher education. These multiple perspectives mean that individuals will interpret the intent of framework statements differently. Depending on the extent of their experiences with new state and national standards, readers may even believe that their current practice is already in alignment with the vision presented for teacher education.

A second reason that policy documents are not sufficient for reform relates to the complexity of the process of reforming teacher education. The changes suggested by any framework represent a complex set of variables involving interactions between faculty from various departments, their curricula, and students from diverse backgrounds. Add to this a need for multiple learning environments including university classrooms, laboratories, K–12 schools and community settings, and the task of reform appears to be overwhelming. The complexity will increase even more as new teacher education programs are developed and evaluated. Dealing with problems of this complexity is not a task commonly undertaken by most teacher educators.

The third reason has to do with the inherent limitations of any framework. While this framework does provide an extensive description of what beginning teachers should know, experience, and be able to do, it does not describe a process for translating the framework into practice. Nor is it designed to serve as a prescribed curriculum, a set of assessment standards or state licensure requirements. Each of these items must still be developed by teams of teacher educators who will translate the framework into actual programs, courses, curricula, and assessments to meet student needs at individual institutions.

A Call to Action

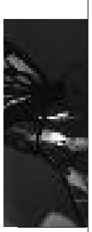
Rodger Bybee (1993) suggests four indispens-able requirements for standards-based reform that can be applied to the reform of teacher education in Minnesota. First, we must point all of our efforts in one direction. This framework is an attempt to provide that direction. Second, we must support the standards presented by the framework and use them as a central theme of Minnesota's efforts to reform curriculum, assessment, and instruction in teacher preparation institutions. Third, each of us must become a spokesperson for the document and for reform in teacher education. We must explain, not just to our colleagues, but to all Minnesotans that teachers are the key to enhanced scientific and mathematical literacy for all students. We must tell them why enhanced mathematical and scientific literacy is critical to the

well-being of our nation, and that improved teacher education, as described by this framework, is a critical first step in the reform process. Finally, we must all provide support to those who are involved in the process of implementing the changes associated with the framework.

Conclusion

The transformation of mathematics and science teacher education in Minnesota is an elusive but achievable goal. It will appear to be an insurmountable task only if we fail to work together to accomplish change. Each stake-holder must assume that he/she is a decision maker in the reform process. Each must understand his/her own responsibility in the process, and recognize the long-term commitment that the process requires. When individuals work together as teams, departments, and institutions, those tasks that formerly seemed insurmountable will become merely challenges to be met and overcome. If each of us accepts our role in the process, we will be successful.

> ***"The secret of getting ahead is getting started."***
>
> SALLY BERGER



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American Association for the Advancement of Science

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For further information contact:

American Association for the Advancement of Science
1333 H Street, NW

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Appendices

APPENDIX A: NATIONAL STANDARDS FOR MATHEMATICS AND SCIENCE TEACHING AND TEACHER EDUCATION

Washington, DC 20005
(202) 326–6400

Interstate New Teacher Assessment and Support Consortium

Model Standards for Beginning Teacher Licensing and Development: A Resource for State Dialogue (Working Draft). 1992.

Model Standards in Mathematics for Beginning Teacher Licensing and Development: A Resource for State Dialogue (Working Draft). 1995.

For further information contact:
Council of Chief State School Officers
1 Massachusetts Avenue, NW
Washington, DC 20001
(202) 408–5505

Mathematical Association of America

A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics. 1991.

For further information contact:
Mathematical Association of America
1529 Eighteenth Street, NW
Washington, DC 20036

National Board of Professional Teaching Standards

Draft Report on Standards for National Board Certification. 1994.

For further information contact:
National Board of Professional Teaching Standards
300 River Place, Suite 3600
Detroit, MI 48207

(800) 228–3224

National Council of Teachers of Mathematics

Professional Standards for Teaching Mathematics. 1991.

For further information contact:
National Council of Teachers of Mathematics
1906 Association Drive
Reston, VA 22091-1593
(703) 620–9840

National Research Council

National Science Education Standards. 1996.

For further information contact:
National Research Council
2101 Constitution Avenue, NW
Washington, DC 20418
(202) 334–1399

National Science Teachers Association.

Revitalizing Teacher Preparation in Science: An Agenda for Action. 1994.

NSTA Standards for Science Teacher Preparation. 1992.

For further information contact:
National Science Teachers Association
1840 Wilson Boulevard
Arlington, VA 22201
(703) 243–7100

American Association for the Advancement of Science

Project 2061: Science for All Americans. 1989.

Benchmarks for Scientific Literacy. 1993.

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National Science Teachers Association

Essential Changes in Secondary School Science: Scope, Sequence and Coordination of Secondary School Science. 1989.

For further information contact:
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1840 Wilson Boulevard
Arlington, VA 22201
(703) 243–7100

Minnesotans have helped create the new vision of mathematics and science education since the first national standards document was released in draft form (NCTM's ***Curriculum and Evaluation Standards*** in 1987). The early efforts were largely sponsored by Minnesota Mathematics Mobilization (M^3), a state coalition of K–16 teachers, mathematicians, scientists, business, and government; and by the Minnesota Council of Teachers of Mathematics (MCTM). At several state conferences in the late eighties, Minnesotans met with representatives of national organizations to convey their critiques of emerging documents. A number of Minnesotans were also involved in creating and critiquing the early science documents, and a statewide conference critiquing the NRC Science Standards was sponsored by SciMath^MN in January of 1994.

As the vision for student learning of mathematics and science became clear, the attention in Minnesota turned to the vision of teaching and teacher education that would enable the new ways of learning. M^3 sponsored another series of meetings: a critique of the NCTM ***Professional Standards for Teaching*** draft in 1990; and two Call For Change in Minnesota conferences in 1992 and 1994 that explored the mathematical preparation needed for elementary and secondary teachers.

In the meantime, a group of Minnesota leaders of science and mathematics were meeting to create SciMath^MN, a statewide initiative to accelerate the pace, broaden the impact, and increase the effectiveness of K–12 mathematics and science education in Minnesota. The vision of SciMath^MN, which became a reality in the fall of 1993, is to increase the participation and achievement of all Minnesota students in mathematics and science, and the target of its initiatives are those who shape the opportunities children have for learning and applying knowledge in their adult lives: policymakers, teachers, parents, higher education, and business. A central thrust of the SciMath^MN Transforming Teacher Education effort is the education and continuing professional development of teachers of mathematics and science.

The SciMath^MN Teacher Preparation Committee, composed of representatives from K–12, higher education, and business began meeting as part of the process of creating SciMath^MN. The committee evolved into the Transforming Teacher Education initiative with the following mission:

> ***To begin the process of transforming teacher preparation in mathematics and science so that Minnesota's K–12 teachers are prepared to teach according to the vision of the present and future national mathematics and science education standards, and are prepared to continue learning new content***

and ways of teaching throughout their professional lives.

The first Transforming Teacher Education meeting was held in January 1994 at St. Cloud State University. Participants included representatives from government, business, and the K–12 community, along with scientists, mathematicians, and educators from Minnesota's public and private colleges and universities. The purpose of the conference was "to identify essential elements of knowledge that beginning teachers need to know in order to teach according to current and emerging recommendations for science and mathematics curriculum and teaching." After extensive discussion, those present were able to reach an amazing level of consensus on four dimensions of teacher's knowledge: knowledge of children, schools, content, and pedagogy.

Subsequent Transforming Teacher Education meetings were held in 1994, and 1995. The July 1994 meeting resulted in plans for the next two conferences and for this document. In October 1994 and April 1994, two conferences were held which involved the teacher education community of Minnesota in the process of Transforming Teacher Education. Teams of faculty from each of Minnesota's teacher preparation institutions attended the conferences together. Between the two meetings, teams worked at their institutions to begin the process of examination and revitalization of their programs. In keeping with the basic premise of TTE that the whole university educates the future teacher, institutional teams included representatives from mathematics, science, and teacher educations departments, university administrators and partner K–12 practitioners. For the same reason, teams of community college faculty also participated in the TTE initiative. In July 1995, small teams of Transforming Teacher Education participants came together to complete a final review of ***Transforming Teacher Education: A Minnesota Framework for Mathematics and Science.***

During the 1995–96 school year, SciMath^{MN}'s efforts continue with the publication of this document, two statewide conferences, and with work at 20 Minnesota teacher preparation institutions where dialogue continues regarding the renovation of teacher education in mathematics and science.

Compiled by Dale Pearson

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