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ABSTRACT

Teachers of mathematics are leading a nationwide effort to bring about a complete redesign of both school and college mathematics programs by setting new and more demanding standards for what students must learn about mathematics, as well as for what teachers themselves must accomplish as professionals in the classroom. This brief document is directed to local school boards, school administrators, parents, college and university faculties, policymakers and government, business and industry leaders, members of the media, and teachers. In several short sections it describes why significant change in mathematics education is necessary, what steps have been taken thus far to bring about such change on a nationwide basis, and how demanding the challenges are that teachers face in carrying out the task. The document ends by describing specific actions that can be taken to support the efforts of mathematics teachers to meet the high standards they have set for their profession. Twelve references are followed by lists of members of the Mathematical Sciences Education Board and related publications. (JJK)

Descriptions of the basic issues in mathematics education and associated recommendations presented here by the Mathematical Sciences Education Board (MSEB) have been distilled from three reports of the National Research Council:

Everybody Counts—A Report to the Nation on the Future of Mathematics Education (January 1989)

Reshaping School Mathematics: A Philosophy and Framework for Curriculum (January 1990)

Moving Beyond Myths: Revitalizing Undergraduate Mathematics (April 1991)

Characterizations given of the recommendations found in

Curriculum and Evaluation Standards for School Mathematics (National Council of Teachers of Mathematics, March 1989),

Professional Standards for Teaching Mathematics (National Council of Teachers of Mathematics, March 1991), and

A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics (Mathematical Association of America, March 1991)

have been checked for general validity by representatives of the National Council of Teachers of Mathematics and the Mathematical Association of America; however, the MSEB assumes ultimate responsibility for their accuracy and appropriateness.

Perspectives on School Mathematics

Counting on You

Actions Supporting Mathematics Teaching Standards

Mathematical Sciences Education Board
National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Frank Press and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.

The Mathematical Sciences Education Board was established in 1985 to provide a continuing national overview and assessment capability for mathematics education and is concerned with excellence in mathematical sciences education for all students at all levels. The Board reports directly to the Governing Board of the National Research Council.

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Copies of this report may be purchased from the Mathematical Sciences Education Board, 818 Connecticut Avenue, NW, Suite 500, Washington, DC 20006.

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Contents

Overview

Momentum for change in U.S. education has been increased significantly by new national education goals set by the President and governors. Attaining these demanding goals will require much more than renewed dedication and concerted effort. The challenge before the nation is to restructure education fundamentally—what is taught, how it is taught, and how we evaluate the results. One field in which there is urgent need for such restructuring is mathematics.

Teachers of mathematics are leading a nationwide effort to bring about a complete redesign of school and college-university mathematics programs. By means of an unprecedented series of publications, they have set new and more demanding standards for what our students must learn about mathematics and for what the teachers themselves must accomplish as professionals in the classroom.

This brief document from the Mathematical Sciences Education Board is directed to school boards, school administrators, parents, college and university faculties, policy makers and government, business and industry leaders, members of the media, and teachers. In several short sections it describes why significant change in mathematics education is necessary, what steps have been taken thus far to bring about such change on a nationwide basis, and how demanding the challenges are that teachers face in carrying out the task. The document ends by describing specific actions you can take to support the efforts of mathematics teachers to meet the high standards they have set for their profession.

The principal message of *Counting on You* is that teacher professionalism holds the key to success in mathematics education reform, provided we support the profession by making the following changes:

- **Recognize and reward effective mathematics teaching.**
- **Support and celebrate mathematics learning for all students.**
- **Strengthen the preparation of teachers of mathematics.**
- **Recognize the importance of the continuing education of teachers of mathematics.**
- **Tie local and state educational objectives to existing national curriculum and evaluation standards in mathematics.**
- **Be certain that tests and other assessments reflect the full set of educational objectives in the curriculum standards.**

With your help and commitment, we can create a climate within which teacher professionalism flourishes and mathematics education is revitalized to meet our nation's goals and the needs of today's students.

Our National Challenge

U.S. students should be first in the world in mathematics and science achievement by the year 2000. So states the fourth of six national education goals set in 1990 by the President and the governors of the 50 states. This special focus on mathematics and science education reflects a growing awareness of their direct impact on:

- The quality of the nation's work force—its ability to function well in an increasingly technological workplace.
- The ability of business and industry to compete effectively in the international marketplace.
- The ability of each of us to carry out our roles as worker and citizen in a world increasingly shaped by mathematics, science, and technology.

Other industrialized countries awakened 20 years ago to the significance of mathematics and science proficiency for their national well-being and began efforts to strengthen these components of education. We in the United States have been too slow to respond. As a result, we face these harsh realities today:

- When compared with students of other nations, U.S. students lag far behind in mathematical and scientific accomplishment.
- Too many students, including a disproportionate number from minority groups, leave school without having acquired the mathematical and scientific literacy necessary for the workplace or for productive lives.
- Public attitudes, which are reflected and magnified by the media, encourage low expectations in mathematics and science. Only in these subjects is poor school performance socially acceptable.
- Curricula and instruction in our schools and colleges are years behind the times; they do not reflect the increased demand for higher-order thinking skills, the greatly expanded uses of mathematics and science, or what we now know about the best ways for students to learn these subjects.
- Calculators and computers have had very little impact on mathematics and science instruction, in spite of their great potential to enrich, enlighten, and expand students' learning.
- Commonly employed methods of evaluation—especially standardized, paper-and-pencil, multiple-choice tests of "basic skills"—are themselves obstacles to the teaching of problem-solving and higher-order thinking skills, as well as to the use of calculators and computers.

For U.S. students to excel in mathematics and science achievement by the next decade, much more will be required than merely trying harder or tightening outmoded accountability measures. A fundamental restructuring must take place nationwide—changing what is taught, the way it is taught, and how we evaluate the results—and it is needed as rapidly as possible. In a highly decentralized system of education, this is a formidable challenge.

Changing Mathematics Education

In response to this challenge, a coordinated national reform effort is being led by the nation's teachers of mathematics. Its plan for restructuring school and college-university mathematics programs starts with fundamental redirections of curriculum and instruction. These are most easily described as changes in what we want students and teachers to be able to do.

Goals for student performance are shifting from a narrow focus on routine skills to development of broad-based mathematical power.

Broad-based mathematical power refers to the students' ability to discern relationships, reason logically, and use a range of mathematical methods to solve a wide variety of non-routine problems. The repertoire of skills that now undergird mathematical power includes not only some traditional paper-and-pencil skills but also many more powerful capabilities. All of today's students must be able to:

- Perform mental calculations and estimates with proficiency.
- Decide when an exact answer is needed and when an estimate will serve the purpose.
- Know which mathematical methods are appropriate in particular contexts.
- Use a calculator correctly, confidently, and appropriately.
- Estimate orders of magnitude to confirm mental or calculator results.
- Make decisions based upon the collection, representation, and interpretation of real data.
- Use tables, graphs, spreadsheets, and statistical techniques to organize, interpret, and present numerical information.
- Judge the validity of mathematical and technical information presented by the media and others.
- Use computer software for mathematical tasks.
- Formulate specific questions from vaguely defined problems.
- Select effective problem-solving strategies.

Goals for teacher performance are shifting from authoritarian models based on "transmission of knowledge" and "drill and practice" to student-centered methods featuring "stimulation of learning" and "active exploration."

In both schools and colleges the familiar classrooms of passive students who are expected to sit and absorb rules that appear as arbitrary dicta gradually are giving way to learning environments that:

- Encourage students to explore.
- Help students to verbalize their mathematical ideas.
- Show students that many mathematical questions have more than one right answer.
- Teach students, through experience, the importance of careful reasoning and disciplined understanding.
- Provide evidence that mathematics is alive and exciting.
- Build confidence in all students that they can learn mathematics.

Change has begun. But efforts to make these visions of student and teacher performance the norm in the nation's mathematics classrooms must proceed steadily for many years, on many levels simultaneously, with the broad involvement of all of the constituencies at each stage. At national, state, and local levels, significant efforts are now under way to improve curricula, teaching, and assessment practices. Major projects are being started to help the diverse efforts of business, industry, government, volunteer groups, and educational organizations to focus on common objectives. The cornerstones of this comprehensive effort are new and more demanding curricular and instructional objectives on which national consensus can be reached.

Curriculum Standards

The 1989 *Curriculum and Evaluation Standards for School Mathematics* of the National Council of Teachers of Mathematics (NCTM) are a milestone in the history of education in our country. Included are forward-looking goals, describing with appropriate specificity the teaching profession's best judgment of what students should learn about mathematics at various ages. These guidelines provide school mathematics programs across the nation with a common philosophy and framework—a universal set of interrelated concepts and methods held together by a simple workable philosophy, yet flexible enough to allow for local and regional variations.

The curriculum standards, designed to introduce more of the breadth and power of the mathematical sciences to students, articulate five general goals for all students:

- Learn to value mathematics.
- Become confident in the ability to do mathematics.
- Become mathematical problem solvers.
- Learn to communicate mathematically.
- Learn to reason mathematically.

Presented separately for grades K-4, grades 5-8, and grades 9-12, the standards specify.

- **Elementary school mathematics that provides an effective foundation for the mathematical sciences.**

  If students are to be better prepared mathematically for vocations, as well as to function as citizens, elementary school mathematics must include substantial subject matter other than arithmetic, including basic elements of geometry, measurement, data analysis, and probability. Each of these topics plays a distinctive role in making the elementary school mathematics curriculum more interesting and relevant to students. Each can be expanded upon throughout the school years.

- **Middle school mathematics that emphasizes the practical power of mathematics.**

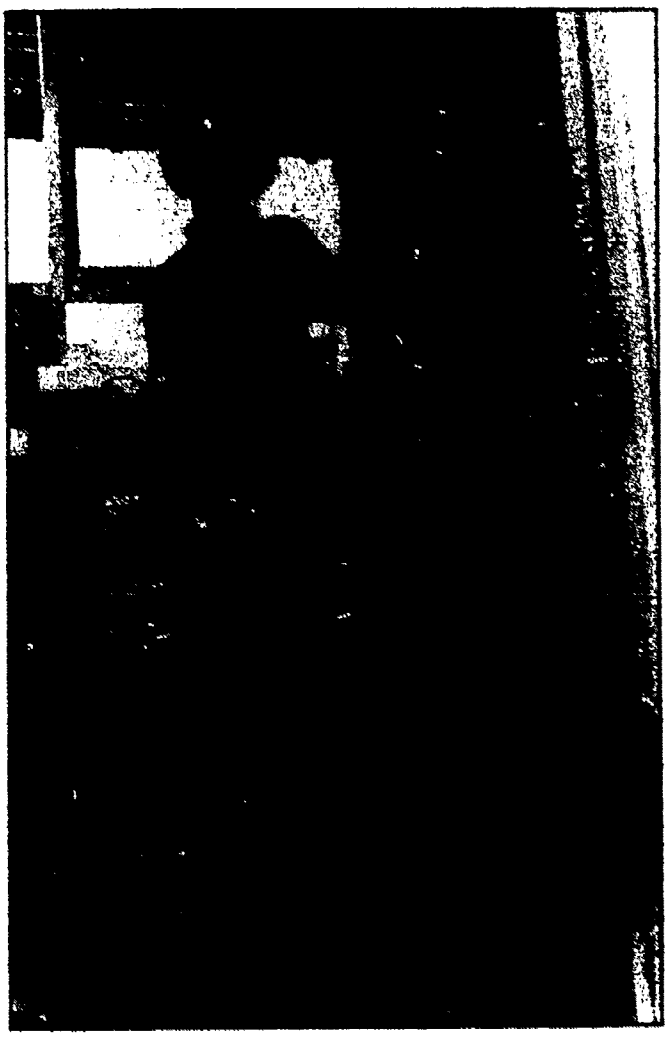
  If instruction is to give students mathematical power, then problem solving needs to be emphasized throughout all grades. Students need to perceive mathematics as a discipline of reasoning that enables them to attack and solve problems of increasing difficulty and complexity. The middle school grades should not be viewed as a time for consolidation or as a pause for rest, but instead should be an essential part of a child's mathematical development. Its focus should be on mathematics for everyday life, a theme rich in motivation that leads naturally to many important mathematical topics (e.g., geometric measurement, interest rates, and spreadsheet analysis) and relates them to other school subjects.

- **Secondary school mathematics that introduces the entire spectrum of the mathematical sciences and shows the power of abstraction, yet includes a common core of broadly useful mathematics.**

  Secondary school mathematics must prepare students for the workplace, for college, and for citizenship. To meet these objectives, the curriculum must

include a broad range of topics reflecting the full power of the mathematical sciences: algebra, geometry, data analysis, discrete mathematics, and optimization. Developing fluency with symbols and other abstract entities, which can be geometric, algebraic, or algorithmic, must be a central aim of secondary school mathematics. Students should learn that, in mathematics, reasoning is the standard of truth. They should experience the power of its applications.

Virtually every professional mathematical science organization in the United States has joined with the NCTM in endorsing and promoting the vision of school mathematics described in the *Curriculum and Evaluation Standards for School Mathematics.*



The professional organizations listed below have added their support for the quality mathematics curricula and assessment criteria provided by the *Curriculum and Evaluation Standards for School Mathematics:*

American Association of Physics Teachers
American Association of School Administrators
American Chemical Society
American Federation of Teachers
Association for Supervision and Curriculum Development
Council for Basic Education
Council for Exceptional Children
Council of Chief State School Officers
Council of the Great City Schools
International Reading Association
International Technology Education Association
Junior Engineering Technical Society
National Association for the Education of Young Children
National Association of Biology Teachers
National Association of Elementary School Principals
National Association of Secondary School Principals
National Association of State Boards of Education
National Catholic Education Association
National Congress of Parents and Teachers
National Council for the Social Studies
National Council of Teachers of English
National Education Association
National School Boards Association
National Society of Professional Engineers

This broad support by the many constituencies of education means that the NCTM guidelines can be viewed properly as the *nation's standards* for what young people ought to know about mathematics.

Teaching Standards

In 1991 school and college teachers of mathematics have taken another significant step by issuing *Professional Standards for Teaching Mathematics* (NCTM) and *A Call for Change: Recommendations for the Mathematical Preparation of Teachers of Mathematics* (Mathematical Association of America). These reports set forth goals and standards for the teaching of school mathematics and address the corresponding changes needed in college-university preparation of teachers. Like the curriculum standards that preceded them, these teaching standards respond to the major challenge of the 1990s cited earlier: to produce the trained work force and the mathematically literate citizenry the nation needs.

Professional Standards for Teaching Mathematics is a set of guidelines representing the profession's best judgments as to what the modern teacher of mathematics must know and be able to do. The standards are very demanding and call for both increased knowledge and a marked departure from the classical model of the teacher as a lecturer. The most useful metaphor for describing the modern teacher is that of an intellectual coach. At various times this will require that the teacher be:

- *A role model* who demonstrates not just multiple paths to a solution but also the false starts and higher-order thinking skills that lead to the solutions of problems.
- *A consultant* who helps individuals, small groups, or the whole class to decide if their work is keeping "on track" and making reasonable progress.
- *A moderator* who poses questions to consider but leaves much of the decision making to the class.
- *An interlocutor* who supports students during class presentations, encouraging them to reflect on their activities and to explore mathematics on their own.
- *A questioner* who challenges students to make sure that what they are doing is reasonable and purposeful and who ensures that students can defend their conclusions.

A Call for Change describes the content and experiences needed by prospective and practicing teachers as they study undergraduate mathematics. Standards common to the preparation of mathematics teachers at all levels are presented with specific recommendations for degrees and course work for the K-4, 5-8, and 9-12 grade levels. The report notes that these preparation standards imply that there should be basic changes in undergraduate mathematics. Content must be revised so that:

- Teachers come to view mathematics as a system of interrelated principles, and they appreciate the development of mathematics historically and culturally.
- Teachers gain experience in building mathematical models, in using technology, and in communicating mathematics orally and in writing.

The presentation of undergraduate mathematics must change so that it models the kind of instruction students will be expected to emulate later as teachers. Colleges and universities must be ever mindful that teachers teach as they were taught—not as they were taught to teach.

Since would-be teachers in college classes do not come with labels on their foreheads, the implication of these teacher preparation standards is that there must be a fundamental restructuring of undergraduate mathematics for *all* students: one that parallels the restructuring under way in school mathematics.

Teacher Professionalism—Key to Success

Both day-to-day improvement and the success of more dramatic restructuring efforts depend ultimately on teachers, who form a dedicated and energetic pool of talent that can help the nation increase the return on its education investment, but only if they are empowered to do so. The key is *teacher professionalism*—the assumption by teachers of more complete responsibility for the quality of education and the simultaneous provision by society of the respect and support teachers require to get the job done.

Teachers of mathematics have assumed the responsibility for setting high standards. The task they have set—bringing the nation's schools and colleges up to these standards—is very demanding and will take many years to accomplish. Teachers need to approach this task in a highly professional way, and they need to be provided the sustained support and working environments that will make it possible for them to carry out their vital mission.

The teacher is the gatekeeper to mathematics for our students. What the teacher knows and believes about mathematics, about teaching mathematics, and about the teaching and learning environment determine what students learn and how they will play out their roles as citizens. This much is generally appreciated. What is less widely understood is how constraints other than the knowledge and experience of the teacher can control the classroom. The nature of the curriculum, the choice of learning materials, and the means of testing stu-

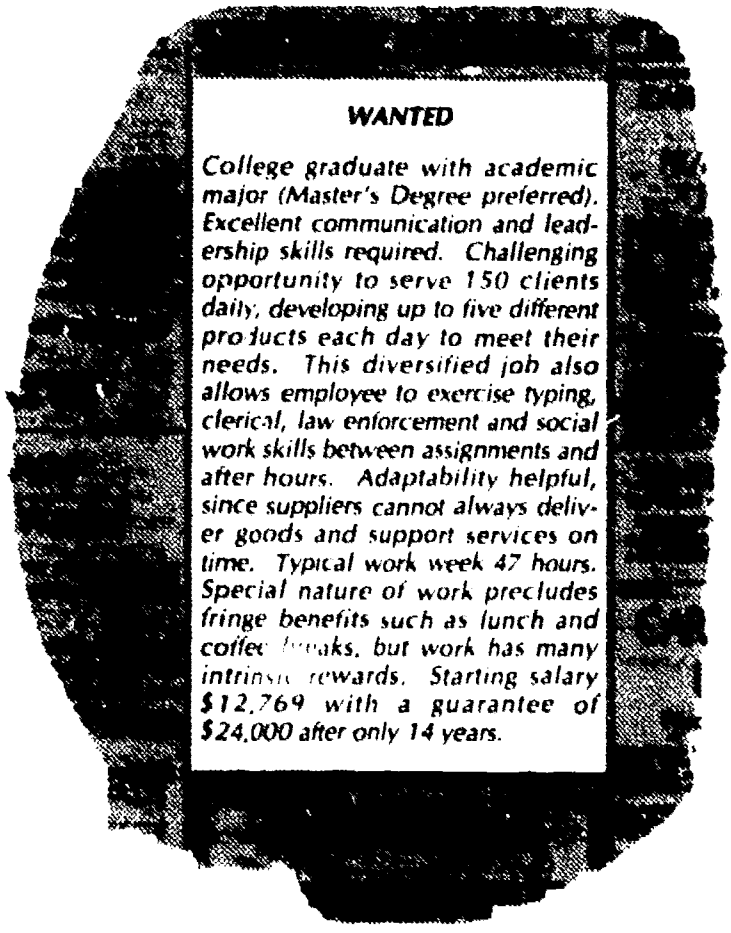
dents all can work against the best interests of learning if they are imposed "top down." To ensure that mathematics education in our schools is of the highest caliber, we must have well-prepared teachers who have the ability and authority to change within reasonable bounds the nature of their own roles and the nature of their classroom environments.

Professional Development

Teachers need much more than sound preparation and freedom from unreasonable constraints. They need comprehensive programs of staff development that enable them to accept responsibility for their own professional development:

- Experimenting with alternative approaches and strategies in the classroom.
- Discussing issues in mathematics, mathematics teaching, and learning with colleagues.
- Learning with students, for students, and from students.
- Maintaining knowledge of contemporary mathematical practice.
- Proposing, designing, and evaluating mathematics programs for students and for professional development.
- Participating in workshops, courses, and other educational opportunities specific to mathematics.
- Participating in school and community efforts to effect positive change in mathematics education.

Are teachers treated like professionals today? In other nations they are. In our country, typically they are not. Some would say U.S. teachers are treated more like hired hands. Linda Darling-Hammond captured the essence of how we treat teachers and what we expect of them in a satirical advertisement she created in 1984:



The fact that teachers in the United States do not have the high level of professional status and respect afforded their counterparts in other countries has been a significant factor in our nation's inability to respond to the educational challenges it faces. As each cycle of would-be education reform comes around, we exhort teachers to do better, lament their poor preparation in college, search for additional ways to hold them accountable, and generally treat them as objects in need of repair.

In the current cycle of reform, U.S. teachers of mathematics have—more strongly and more effectively than any other group in the nation—risen to the challenge presented by the President and governors. Through their standards they have set the agenda for reform. Few teachers in today's schools have the authority or resources necessary to carry out this agenda. But as schools evolve from a model with teachers as hired hands to one in which teachers function as professional educators, they should welcome the challenge to implement national standards for mathematics education.

Action Plan

Following are actions you can take to support mathematics teacher professionalism.

Schools Boards and School Administrators

- Establish mathematics goals and programs in your schools that are consistent with national standards for curriculum and evaluation.
- Provide sufficient resources (equipment, time, and budget) to support an instructional program meeting the standards.
- Discontinue use of standardized tests that are misaligned with national standards for curriculum.
- Provide time for your teachers: time to plan and evaluate their own teaching, consult with colleagues about teaching, and confer with supervisors about teaching effectiveness.

- Give your teachers freedom to exercise their ability, judgment, and authority, and involve them in decision making.
- Institute a comprehensive inservice program consistent with national standards, and involve teachers in its development and planning.
- Evaluate teachers using information gathered from various sources—the teacher's goals and plans, students' accomplishments, repeated classroom observation—and national professional standards.

Parents

- Discuss with your children the importance of mathematics for their future.
- Instill in them the idea that they can learn mathematics.
- Encourage your children to study mathematics every year they are in school.
- Inform yourself about national curriculum and teaching standards in mathematics.
- Ask your superintendent and school board how they plan to meet the standards.
- Ensure that school budgets are adequate to meet the needs of all students.

College and University Faculties

- Establish mathematics programs consistent with national standards for curriculum and mathematical preparation of teachers.
- Explore effective alternatives to "lecture and listen" to involve students actively in the learning process.
- Teach future teachers in the ways they will be expected to teach.

- Develop with teachers and school systems appropriate inservice courses to support ongoing professional development.
- Align institutional admissions and placement testing practices with contemporary standards for school mathematics.

Media

- Interpret for the public the process of change in mathematics and science education.
- Inform the public about the new standards for curriculum, teaching, and assessment in mathematics.
- Help counteract stereotypes that hinder women and minorities from achieving their full potential in science and mathematics education.
- Report on mathematical success stories of students and teachers.
- Promote a positive image of mathematics and its importance to the economic future of the United States.

Policy Makers and Government

- Develop accountability procedures that measure progress toward meeting national standards of mathematics competence for all students.
- Enforce teacher certification and evaluation guidelines based upon national standards set by the mathematics community.
- Plan and implement large-scale programs to equip classrooms with the technology required today for the teaching of mathematics.
- Plan and fund a nationwide teacher enhancement program aimed at bringing all teaching up to the level of the NCTM standards.

- Support systemic change based on the mathematics community's standards for curriculum, instruction, and evaluation.

Professional Organizations

- Provide professional development opportunities for teachers of mathematics.
- Conduct extensive public information campaigns on the importance of effective mathematics education and public policy changes to support it.
- Recognize exemplary teachers of mathematics and programs.
- Stimulate and participate in local, state, and national implementation networks.
- Establish curriculum guidelines for undergraduate mathematics consistent with national standards for school mathematics.

Business and Industry

- Communicate the mathematical needs of the work force to K-16 education administrators, curriculum developers, and faculty.
- Participate in local and state coalitions that are working to improve mathematics education.
- Join with other corporations actively working to ensure that schools implement the NCTM standards for school mathematics.
- Insist that state and local school systems adopt assessment practices that are aligned with employers needs for workers who can think.
- Provide summer jobs and academic year opportunities for teachers to enrich the curriculum with real-world examples.

Counting on You

The vision of where we want to be by the year 2000 has been created; teachers have charted the course for getting us there. What is needed now is action in support of the teachers' goals and the sustained energy to achieve them. Experimentation and research will be required as we seek to develop curricula, find new and effective approaches to teaching, and map new strategies for assessment.

As noted in the *Professional Standards for Teaching Mathematics,*

> *If we make a long-term commitment to the standards, . . . if we approach the task with the will to persevere, if we are critical of the steps we take, . . . we will make progress toward the goal of developing mathematical power for all students.*

Your strong support is crucial to progress. We all have a share in the investment of our students' mathematics education, and we all want a real return on our investment. In 1989 Americans took notice of the fact that *Everybody Counts.* Now, because teachers cannot restore the vitality of mathematics education alone, they and their students are counting on **YOU.**

Resources

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David K. Cohen, Interim Dean, College of Education, Michigan State University, *Liaison from Commission on Behavioral and Social Sciences and Education*

Staff

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Related Publications

The principal message of *Counting on You* is that teacher professionalism holds the key to success in mathematics education reform, if the necessary support is provided. Related publications of the National Council of Teachers of Mathematics, the Mathematical Association of America, and the National Research Council are important for the context of this document and the goals of improving mathematics learning for all students.

From the National Council of Teachers of Mathematics

Professional Standards for Teaching Mathematics (#439S3)

Curriculum and Evaluation Standards for School Mathematics (#396S3)

Single copies of the above are available at $25 each. To order or to inquire about multiple copy purchase, contact:

The National Council of Teachers of Mathematics
1906 Association Drive
Reston, VA 22091
Phone: 703/620-9840, or for orders only, 800/235-7566

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