# Developing World Class Students through World Class Mathematics Standards: Do Minnesota's Standards, Students, and Teaching Measure Up?

**SciMath^MN Briefing for State Policymakers**
**January 2007**

## Introduction

In the 1986 movie *Peggy Sue Got Married*, looking ahead to her future life as a homemaker, Peggy Sue declares: "There is no algebra in my future." Twenty years later, no young woman (or man) can afford to make that statement. In fact, we simply cannot afford to raise another generation of math phobic adults. Students who graduate from Minnesota high schools need to be well grounded in the mathematics that elevates the achievement of Minnesota students from being among the best in the United States to being among the best in the world–a goal we have not yet reached.

- **Minnesota needs world class standards to support the state economy and prepare future citizens**
- **Knowing and understanding contemporary mathematics is a key competency for a highly qualified workforce and citizenry**
- **To be effective, standards must be part of a world class system, which also includes textbooks and other learning materials, instruction, assessments, preparation of teachers, and ongoing professional development for practicing teachers – all aligned with the standards**

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Minnesota needs world class standards in mathematics if the state is to prepare today's students to be tomorrow's skilled workers in a global economy. To be world class, standards must:

- Include the important mathematics critical to a 21st Century economy
- Integrate skills, concepts, and applications
- Be focused and coherent with a small number of attainable topics for each grade
- Be taught well by knowledgeable and effective teachers
- Be embedded in a world class system that aligns assessment, instruction, textbooks and other learning materials

It is the position of SciMath^MN that every student should study significant mathematics every year of their K-12 school life. Significant mathematics includes traditional topics in number, geometry and algebra, plus important newer workforce and research tools such as data analysis, discrete mathematics, and spreadsheet manipulation.

## How can we define world class mathematics standards?

There is no international definition of high quality mathematics standards for students. However, it makes sense to examine the goals for learning and the system for delivery of that learning in those countries whose students demonstrate outstanding performance on international assessments, especially those countries that have been consistently high-performing over time. Such countries include Singapore, Japan, Korea, Finland, the Netherlands, and the Czech Republic.

Based on this examination, we can say that world class standards meet the following set of criteria:

- Are focused, coherent, and non-repetitive
- Specify a small number of attainable topics at each grade, topics that can be taught effectively at that grade
- Reflect guidelines such as the recent National Council of Teachers of Mathematics' document, *Curriculum Focal Points*, which outlines 3 big ideas at each grade, PK-8
- Are specific enough to guide development of rich assessments, selection of textbooks, preparation of pre-service teachers, and ongoing renewal of licensed teachers
- Provide a carefully sequenced progression of learning for students K-12, to help all to reach the required level of attainment, in particular algebra by the end of $8^{th}$ grade, and at least 3 credits of high school level mathematics including algebra II, geometry, statistics and probability
- Incorporate a balance of skills, processes, and concepts, leading to understanding, retention, and the ability to apply learning

*World class standards begin with focused, coherent and non-repetitive content, covering a small number of attainable topics at each grade, topics that can be taught effectively at that grade.*

## How can we tell if we currently have world class standards?

Currently Minnesota students are performing well, but not as well as they could or should be. A look at the evidence supports this view.

Our existing state mathematics standards enable many students to achieve as well or better than students in most other states. However, the overall strong performance of state students as a whole disguises the fact that some groups of Minnesota students perform well below the rest, on many measures. Students of color and low-income students take fewer high school mathematics courses, perform less well on assessments, complete high school at lower rates, and complete college at lower rates (Minnesota State Demographic Center, 2006).

Despite the success of Minnesota students when compared to students in other states on national assessments such as the National Assessment for Educational Progress (NAEP) and ACT, a college admissions test, they are less successful on international comparisons. With funding from SciMath$^{MN}$, Minnesota participated in 1995 as a mini-nation in the Third International Mathematics and Science Study (TIMSS). Minnesota students achieved better than the U.S. average in mathematics, but well below the highest performing countries. In science, however, the same students performed in the top group of countries in several areas of science, suggesting differences in the system of instruction, since both tests were given to the same students. In a study that attempted to determine why the same eighth grade students performed better in science than in mathematics,

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several factors were identified as possible explanations. One was that nearly all eighth grade students had the opportunity to learn the same science, while in mathematics some students were still reviewing computation, while others were learning algebra and geometry. Another possible explanation was the fact that the science curriculum offered fewer topics done in more depth, while the mathematics curriculum included a much larger number of topics (NEGP, 2000).

Though Minnesota did not participate in TIMSS-R (repeat) in 1999, or in the Trends in Mathematics and Science Study in 2003, other data at the state level in the interim such as scores on NAEP, the Minnesota Comprehensive Assessments, and the ACT, while showing slight improvement, do not suggest that Minnesota students have risen to the top in mathematics internationally. State participation in TIMSS in 2007 will give us a new look at the international performance of a new generation of students, twelve years later.

Another recent international assessment, the Program for International Student Assessment (PISA), is administered by the Organization for Economic Cooperation and Development (OECD). Unlike TIMSS, which measures student understanding of skills and concepts, PISA focuses on the application of knowledge to problems with a real-life context. Thus while TIMSS might ask students to divide one number by another, PISA might ask them to find the amount of money a traveler would receive given a certain exchange rate; where TIMSS might ask students to evaluate a given equation, PISA asks students to analyze car performance given a table and a weighted formula with which to interpret the table. Both assessments measure components of a mathematics program; both types of learning are necessary and together give a complete picture of learning. Though there is not Minnesota specific data for students' performance on PISA, U. S. students as a whole did comparatively less well than they did on TIMSS, scoring near the bottom of the OECD countries, well below the PISA average. We could expect that Minnesota students would perform better than the U. S. average, but below the highest scoring countries, many of which also participated in TIMSS.

To summarize where Minnesota is now:

- NAEP – continuing high performance relative to other states
- ACT – continuing high performance relative to other states
- TIMSS – moderate performance relative to other countries in mathematics; strong performance in science
- Achievement data masks large gaps between segments of student population
- Lower performing students are in segments of the Minnesota population that are growing fastest
- These same students – students of color and low income students – complete high school at lower rates that other students, and complete college at very low rates

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### Why do we need world class standards in mathematics?

World class standards are necessary for preparing Minnesota students for the $21^{st}$ Century workplace and citizenship. For over 30 years, Clifford Adelman has analyzed student data for the U. S. Department of Education in longitudinal and other studies. He has repeatedly found that the single strongest predictor of completion of a bachelor's degree is the highest level of mathematics completed in high school. Completing a course beyond advanced algebra, such as precalculus or statistics, more than doubles the chance that a student entering college will complete a degree (Adelman, 1999).

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Adelman has also found that the number of college and university mathematics courses taken is the single greatest predictor of lifetime earning potential, cutting across gender and other demographic groups (Adelman, 1994).

Through a law passed by the 2006 Legislature, Minnesota is ratcheting up the expectations for course-taking in mathematics, particularly for higher levels of mathematics in high school. However, just taking courses, and even passing them, does not necessarily insure understanding. Consider the following. According to data collected from the ACT test, 58% of students taking the test have taken the core of "college-ready" courses; yet only 28% of them perform on the ACT as though they have learned the content of these courses, which include mathematics at least through the advanced algebra level (Minnesota Office of Higher Education, 2006). Thus the further challenge is to prepare the system of K-12 education to offer all students not just the challenge, but also the support needed to accomplish the new requirements, and to meet the goals of the standards with understanding.

### What mathematics is included in world class mathematics standards?

All students need to have a functional understanding of—as well as an appreciation of—contemporary mathematics, an understanding robust enough to use in a variety of new situations. It includes algebra for all, not just arithmetic for all and algebra for some, as in the past. Robert Moses, former civil rights worker and Director of The Algebra Project, declares that algebra is the new civil right, stating, "I believe that the absence of math literacy in urban and rural communities throughout this country is an issue as urgent as the lack of registered Black voters in Mississippi was in 1961" (Moses, 2001). Algebra is critically important since it is the gateway to the areas of mathematics most needed for understanding our quantitative world. With a solid foundation in algebra, students can—and should—study topics such as geometry (the mathematics of shape), statistics (the mathematics of data), discrete mathematics (the mathematics of computers), and operations research (the mathematics of business and industry). But mathematical education is not only about topics, it also is about reasoning. The mathematics needed for a technological workplace usually involves using a broad set of mathematical tools, in messy and often ill-defined applications. This requires strong reasoning ability, as well as problem solving and critical thinking skills.

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Mathematics, as done by real people in today's world, is far more complex (and interesting) than the computation most of us remember from our schooling. In the *SciMath^MN Minnesota K-12 Mathematics Framework,* mathematics is defined as having four overlapping defining aspects:

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> Mathematics is the science of patterns. [M]athematicians … anticipate nature. They observe, experiment, and make conjectures. They investigate, measure, calculate, and classify to explore their questions. Mathematics is not a passive pursuit nor a spectator sport, but rather an active attempt to identify, describe, and explain patterns wherever they exist in whatever form. As such, mathematics needs to be taught more often as a laboratory experience, with students asking questions, exploring relationships, explaining their 'theories', and defending their positions and strategies.
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> Mathematics is a universal language for communicating the order in the world. [It has long been the language of science, and] with the advent of computer technology, it has also become the language of manufacturing, finance, social policy … and the technical workforce. Mathematics has its vocabulary, its symbols, its definitions, and expressions which help us internalize and clarify our thinking and communicate our ideas. Learning the language of mathematics requires immersion in meaningful activity and conversation.
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> Mathematics is an art. [As such, it] has a long, fascinating, and continuing history … The potential for mathematical discovery – the "aha" experience – is in all of us. In fact, with the rapid proliferation of mathematical applications in the workplace and the creative arts, students will need many opportunities to be thoughtful and original as they experience mathematics instruction.
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> Mathematics is a tool to solve problems. [People from every walk of life] analyze and solve problems. Problem solving is at the heart of mathematics, and its component skills – exploring, representing, predicting, testing, generalizing, justifying, communicating, and applying – are learned by doing. Mathematics content and instruction must significantly increase students' willingness, perseverance, and ability to pursue and solve problems. These important basics of mathematics cannot be memorized. (SciMath^MN, 1997, p.4)

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Most importantly, mathematics—like all of modern science—is a rapidly changing subject. The impact of computers cannot be overstated. Mathematicians, both pure and applied, are continually developing new techniques that exploit the rapid advances in computation power. From biology to business, mathematical thinking has changed the way we think about our world. In short, mathematics is not done nor used the way it was even twenty years ago. Hence it cannot be taught the way it was taught twenty years ago.

The challenge is immense. We are adding to, not subtracting from, the list of skills our students and teachers must have. Algebra is important, not as an end, but as a means. Our students must be ready to use mathematics in their careers. To do so, they must have both the skills and the enthusiasm to learn and then apply mathematics to the questions around them.

**What kind of teaching is necessary for students to meet world class standards?**

Minnesota's high quality teaching force needs to become even more effective. Teachers use instructional practices that are less than optimal not because they intend to prevent learning, but because, typically, teachers tend to teach the way they were taught and the way they were taught to teach. They are doing the best job possible with ineffective tools and without sufficient access to recent research. To help more students learn mathematics successfully, virtually all teachers will benefit from continual professional learning in the form of high quality professional development to use more effective teaching practices**.**

Teaching practice must incorporate recent cognitive science research on how students best learn mathematics. Recent reports from the National Research Council, such as *How People Learn* (2000), *Adding It Up* (2001), and *How Students Learn Mathematics* (2005), synthesize and summarize results from cognitive science and apply the results to learning mathematics. They emphasize the importance of weaving together the many aspects of mathematics, especially factual knowledge and conceptual understanding, and the necessity of requiring students to reflect on their own learning. Some components of effective instruction that are well supported by research in cognitive science are new to most teachers, and they need to connect the ideas to their teaching, and have multiple opportunities for practice and support as they work to implement the ideas. In the mathematics classroom, practices that yield strong learning include a focus on modeling ideas, generalizing results, and justifying and proving conclusions—what mathematicians, scientists, and engineers actually do.

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In addition to making changes in standards and course-taking expectations for all students, teachers must teach effective mathematics from the earliest grades. At present instruction is sometimes characterized by endless repetition, repetition which is often no more effective the sixth time than it was the first. Traditionally, the content focus in the early grades has been on number and computation. While this is an important component of mathematics, and can provide a foundation for later learning, if topics such as geometry, measurement, and algebraic thinking are not part of instruction from the earliest grades, students will not be prepared for later work.

All students deserve high quality instruction, particularly those students in currently underperforming groups. Elementary teachers are crucial in giving students the foundation to be ready for middle school algebra and challenging high school courses. It may be time to reconsider our expectations that elementary teachers be generalists and teach multiple subjects, leaving little time for preparing to teach new ideas in mathematics or other areas. Several presidents of the National Council of Teachers of Mathematics have called for serious consideration of having elementary and middle grade teachers specialize in teaching mathematics (NCTM, 2006, 2003). Intermediate and middle grade teachers who show interest and ability in teaching mathematics might focus on teaching mathematics to multiple classes, either at one grade, or over several grades or serve as coaches to teachers. Nationally, most elementary teachers have minimal preparation in mathematics at the college/university level; in fact, nationally only 7% of elementary teachers majored or minored in mathematics education (NCTM, 2000). Requirements for licensure are usually one or two courses in mathematics. In addition, since we expect most elementary teachers to teach classes in many subjects each day, they do not have sufficient time to prepare for the demands required to give all students the necessary foundation for algebra in eighth grade. Models that allow specialization, where fewer teachers are responsible for multiple classes in mathematics, show promise. In addition they are pragmatic in focusing professional development dollars on a smaller number of teachers rather than attempting to train all elementary teachers in all academic subjects over multiple years.

**What does a world class system look like?**

The primary component for a system of effective learning is a guaranteed and viable curriculum. This means having a K-12 course of study that gives all students the opportunity to learn significant mathematics, with a small number of effectively taught topics each year.

Such a system requires all its parts to be in alignment. This means that the standards be supported by instructional practices that enable all students to achieve the standards. This in turn requires that all teachers understand and be prepared to deliver such instruction. It also requires that all instructional materials, including textbooks, support and align with the standards. In a world class system, assessment must also be aligned with the standards, not only in terms of topics, but by having a balance of skills, concepts, and applications, demanding that students demonstrate reasoning, problem solving, and critical thinking. Since what is tested becomes what is valued in the classroom and community, testing must emphasize the kinds of learning we value, not simple the easy-to-test knowledge at the lowest cognitive levels. Finally, teachers at all levels in a world class system must participate in ongoing reflection and renewal in order to prepare them to support powerful learning for all students.

**Conclusion**

With all these components in place – standards that are focused, coherent, and based on powerful contemporary mathematics, teachers who are well-prepared and up to date in their instructional practices, and an entire system of standards, textbooks, tests, teacher preparation, and ongoing professional development that is aligned – Minnesota will produce students who have embarked on a path to rise to world class status and achievement and graduates who will be ready to compete in a global economy.

What questions remain?

- Will the revision of Minnesota's Academic Standards for Mathematics contain the focus and content needed to produce world class achievement in mathematics?
- Since standards alone are not enough, will ongoing professional development that helps instruction deepen and guarantee that all students achieve the standards be provided for all teachers?
- If algebra is a means and not an end to world class achievement, will we provide students with a K-12 and beyond education in

- mathematics that is inclusive of multiple areas of contemporary mathematics?
- How might we strengthen the beginning stages of learning mathematics at the elementary levels of education?
- Are all parts of the system aligned, both in districts and at the state level, to enable us to meet Minnesota's diverse workforce needs?

The challenge ahead is certainly one that Minnesota can meet, with the collaboration of all involved. We stand read to meet this challenge.

## Contact

Nancy Nutting
Executive Director
651-221-2590
scimathmn@comcast.net
www.scimathmn.org

SciMath$^{MN}$
Science Museum of Minnesota
120 W. Kellogg Blvd.
St. Paul, MN 55102

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