SOUND off!

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The Future of High School Mathematics

Results from the 2012 Program for International Student Assessment (PISA), released on December 3, 2013, showed once again that U.S. high school students are only in the middle of the pack when it comes to science, mathematics, and literacy achievement (OECD 2013). The findings quickly elicited an outburst of public hand wringing, criticism of U.S. schools and their teachers, and calls to emulate the curriculum and teaching practices of high-achieving countries. Then, quite predictably, there were a variety of explanations as to why we cannot import the policies and practices of other quite different countries. Instead, policymakers and pundits with little expertise in mathematics or experience in mathematics education urged schools to redouble efforts along lines that have been largely ineffective for the past decade and are not common in any high-performing country—a regimen of extensive standardized testing with mostly punitive consequences for schools and for teachers who fail to make adequate yearly progress. Public attention to the challenge of international competition soon faded, and we will hear little about the meaning of PISA results until the next wake-up call arrives.

WHAT MIGHT HAPPEN IF WE TRIED SOMETHING DIFFERENT?

Countries that have made real progress in their performance on international assessments share several characteristics. First and foremost is broad agreement on the goals of education and sustained commitment to change over time. In the United States, there has been steady improvement in student mathematics performance at the elementary school and middle school levels on the National Assessment of Educational Progress (NAEP) and some improvement in results on Advanced Placement and college entrance examinations over the past two decades—a period when efforts have been guided by the National Council of Teachers of Mathematics (NCTM) Standards for curriculum, evaluation, teaching, and assessment.

Over the past three years, forty-five of the fifty U.S. states have been engaged in an effort to implement the Common Core State Standards (CCSS) for Mathematics and English Language Arts. With respect to mathematics, those standards, prepared under the aegis of the National Governors Association with generous private financial support, in many ways extend key ideas in the earlier NCTM Standards (NCTM 2000). Despite understandable controversy about particulars of the CCSS and the processes by which they were developed and the processes by which states were induced to adopt them, the Common Core standards provide a useful framework for further efforts, *provided they are viewed as a living document to be modified as recommended by experience.*

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WHAT SHOULD STUDENTS, TEACHERS, PARENTS, AND POLICYMAKERS LOOK FOR IN THE EMERGING REFORM OF HIGH SCHOOL MATHEMATICS?

From our perspective—as mathematicians, teachers, statisticians, teacher educators, and curriculum developers with extensive experience in school mathematics innovation—there are five key elements of the Common Core program that provide a basis for productive change in U.S. high school mathematics:

• ***Comprehensive and Integrated Curriculum***—The traditional American high school mathematics curriculum consists of two yearlong courses in algebra and a one-year course in geometry. The CCSS for mathematics retain essential elements of those topics, but they also prescribe attention to important concepts and skills in statistics, probability, and discrete mathematics that are now fundamental in computer, management, and social sciences. The Common Core guidelines also describe an attractive integrated curriculum option—suggested by the common practice in other countries of addressing each mathematical content strand in each school year. That international curriculum design helps students learn and use the productive connections among algebra, geometry, probability, statistics, and discrete mathematics.

A broad and integrated vision of high school mathematics would serve our students better than the narrow and compartmentalized structure of traditional programs.

• ***Mathematical Habits of Mind***—For most people the phrase "do the math" means to follow standard algorithms for calculation with whole numbers, fractions, decimals, and the symbolic expressions of algebra. But productive quantitative thinking also requires understanding and skill in mathematical "sense making" (Martin et al. 2009) and use of what the Common Core Standards call *mathematical practices*. To apply mathematical concepts and methods effectively in the kind of realistic problem-solving and decision-making tasks that PISA assessments highlight, students need to develop the habits of (1) analyzing complex problems and persevering to solve them; (2) constructing arguments and critiquing the reasoning of others; (3) using mathematical models to represent and reason about the structure in problem situations; and (4) communicating results of their thinking in clear and precise language.

Developing important mathematical habits of mind, especially the process of mathematical modeling that is required to solve significant real-world problems, should become a central goal of high school instruction.

• ***Balanced Attention to Technique, Understanding, and Applications***—One of the most common student beliefs about mathematics is that what students are asked to learn is not supposed to make sense and bears little relationship to the reasoning required by everyday life. Those views are expressed well in the whimsical rhyme about division of common fractions, "Yours is not to reason why; just invert and multiply," and the common student question, "When will I ever use this stuff?" Unfortunately, many teachers encourage those beliefs about mathematics learning by suggesting that understanding and application of mathematical ideas and methods can occur only after rote mastery of technical skills.

Findings of cognitive and curriculum design research over the past two decades challenge such conventional beliefs and common practices. Curricula and teaching that engage students in collaborative exploration of realistic problems have been shown to be effective in developing student mathematical understanding, skills, and problem solving simultaneously. These problem-based approaches in the classroom also develop students' disposition to use mathematics as a reasoning tool outside school.

Improved performance on international assessments like PISA are likely to result from moves toward curricula and teaching methods that balance and integrate mathematical techniques, understanding, and applications.

• ***Information Technologies***—Powerful tools that allow users to process visual and quantitative information with mathematical methods are now ubiquitous in American life. The CCSS recommend helping students learn to "use appropriate tools strategically." But the Common Core standards and schools are only beginning to respond to the profound implications of information technology for teaching and learning. If it is possible to simply ask your cell phone to perform any of the routine calculations taught in traditional school arithmetic, algebra, and calculus courses, what kind of mathematical learning remains essential? If those same tools can be applied to support student-centered exploration of mathematical ideas, how will the new learning options change traditional roles of teachers and students in the mathematics classroom and raise expectations for the mathematical challenges that students can tackle?

Intelligent response to the challenges and opportunities presented by information technologies will require creative research and development efforts and the courage to make significant changes in traditional practices.

• ***Probing and Useful Assessments***—One of the clearest findings of educational research is the truism that what gets tested gets taught. PISA is not a perfect or complete measure of high school student achievement. Neither are the TIMMS international assessments, the NAEP tests, the SAT and ACT college entrance exams, college placement exams, or, quite likely, the coming assessments attached to the Common Core State Standards (Larson and Leinwand 2013).

Some would respond to the inadequacy of current assessment tools by sharply curtailing high-stakes standardized testing; others would increase the testing and raise the consequences for students and schools who perform poorly. It is almost certainly true that the best course lies somewhere between those extremes.

We need new and better tools for assessing student learning—especially in the areas of mathematical modeling, problem solving, and quantitative reasoning. Then we need to see that those assessments are used in constructive ways to help teachers improve instruction and to inform educational policy decisions.

WE NEED A CHANGE IN THE CULTURE

Mathematics educators who have been active in reform efforts for the past two decades will probably point out that our ideas for the future of high school mathematics have been expressed in earlier policy documents and curriculum projects inspired by the NCTM Standards. But it seems safe to say that we have a long way to go before those recommendations are common practice in most U.S. high schools. The force of tradition in education makes its aims and practices consistently and powerfully resistant to change.

Mathematics teachers, curriculum developers, and researchers have made significant progress in developing and testing efficacy of comprehensive and integrated curriculum structures; of problem-based teaching that develops student skill, understanding, and problem solving; of strategies for teaching mathematical practices like modeling complex realistic situations; of the use of technology for doing and teaching mathematics; and of assessment for breadth and depth of learning. However, *if that progress is to be sustained and broadly implemented, we need to accelerate the pace of innovation.*

To apply national resources to that effort in optimal ways, we must regularly remind ourselves that education is a community responsibility that aims to develop the abilities and interests of all students, not a contest with winners and losers. We need to work together to develop progressive goals for school mathematics and high-quality instructional resources. Most important, we need to change the tenor of public and professional discourse about mathematics education. We need to dial down the acrimonious policy arguments and relentless criticism of schools and teachers. We in the profession need to be articulate and persistent in making the case that teaching is one of the most important and demanding tasks for adults in our society and that teachers deserve our wholehearted encouragement and support.

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