Education Commission of the States

The Progress of Education Reform 2004

Science and Mathematics Education

Vol. 6, No. 1, December 2004

What's inside

- Fewer young people pursue science, math careers
- Science remains second-tier subject
- Teaching math requires special knowledge, skills
- Student performance below par on national tests

Teachers' Knowledge and Skills Are Key To Improving Student Achievement in Science, Math

America's competitive edge in the global economy, the strength and versatility of its labor force, and its capacity to nourish research and innovation all depend on an education system capable of producing a steady supply of young people well-prepared in science and mathematics.

But all along the pipeline – from the quality of science and math instruction in the early grades, to the performance of high school seniors on international tests, to the content and rigor of teacher education programs in the nation's colleges and universities – troubling signs of weakness and deterioration are appearing.

The increasingly urgent need to improve science and math education in America was made clear in a report issued last summer by the National Science Board.

Over the past two decades, the report noted, the U.S. science, engineering and technology workforce has grown at more than four times the rate of total employment, in large part because of the country's ability to integrate large numbers of foreign-born scientists and engineers into the labor force. But in the global marketplace, competition for these workers is steadily widening and intensifying.

At the same time, the number of U.S. citizens qualified to fill science and engineering jobs is stagnating. The number of young people preparing for careers in these fields has declined steeply, and a large portion of the current workforce is rapidly approaching retirement age. Complicating matters, America's college-age population increasingly will be made up of Hispanics and blacks, whose participation rates in science, engineering and technology are half or less those of white students.

This issue of *The Progress of Education Reform* focuses on what is more and more seen as a major stumbling block to change and improvement: the education, training and classroom practices of the nation's K-12 science and math teachers. It summarizes recent research on the dimensions, causes and already emerging consequences of the problem, and looks at efforts under way at the national and state levels to address it.

Science and Engineering Indicators 2004

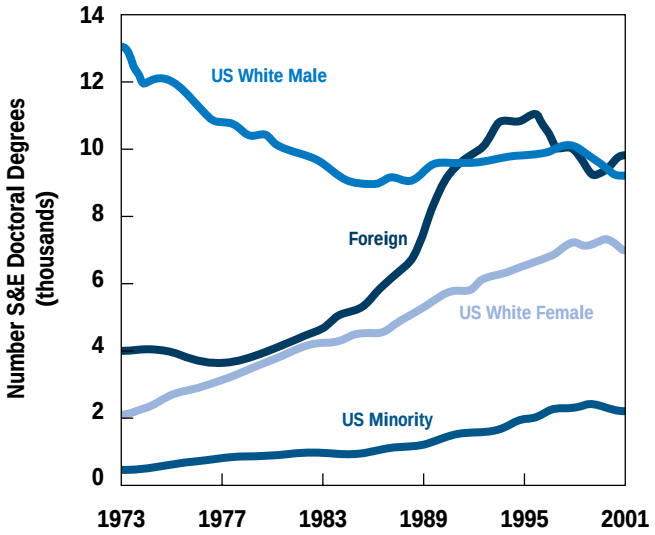
(National Science Foundation and National Science Board, July 2004, http://www.nsf.gov/sbe/srs/seind04/start.htm)

The diminishing number of young people interested in – and prepared for – careers in science, engineering and technology is one of several converging trends that threaten to undermine America's competitive edge in today's knowledge-based global economy.

That is among the major findings of the National Science Board, which every two years takes the measure of scientific and technical capacity worldwide by analyzing a range of national and international demographic, education, labor force, and research and development trends.

The chapters on elementary, secondary and postsecondary education – an easy-to-use mix of tables, charts and explanatory text – paint a mixed picture.

Nearly all states have established academic standards in both science and math, the report notes, and the annual testing of core subjects mandated by the No Child Left Behind Act will be extended, in the 2007-08 school year, to include science. Classroom access to computers and the Internet has expanded significantly in the past several years, as has the availability of Advanced Placement science and math courses. Student achievement in math has risen overall.



U.S. science and engineering doctoral degrees, by sex, race/ethnicity and citizenship status:1973-2001 (*Science and Engineering Indicators 2004*)

On the other hand:

- Large numbers of the nation's middle school and high school students receive science and math instruction from underqualified teachers. For example, nearly 20% of high school students – and more than half of middle school students – study mathematics with a teacher who did not major or minor in mathematics or a related field.
- One in three 8th graders in the United States attends a school that does not offer an algebra class – widely considered a "gatekeeper" course for more-advanced science and math courses.
- In 1975, the United States ranked third in the world in the percentage of students pursuing natural science and engineering degrees. Now it is 17th. Over the past 10 years, the number of high school seniors planning on careers in engineering has dropped more than 35%.

The report concludes with a call for greater efforts – beginning immediately – to attract more students into science and engineering. Otherwise, it warns, "we could reach 2020 and find that the ability of U.S. research and education institutions to regenerate has been damaged and that their pre-eminence has been lost to other areas of the world."

Bayer Facts of Science Education 2004: Are the Nation's Colleges Adequately Preparing Elementary Schoolteachers of Tomorrow To Teach Science?

(Bayer Corporation, May 2004, http://www.bayerus.com/msms/news/facts.cfm?mode=detail&id-survey04)

The Philadelphia-based Bayer Corporation's 10th annual report on science education in America concludes that efforts to improve elementary school science have yielded only marginal gains over the past decade. Science, it says, remains a second-tier subject, both in teacher training programs and elementary classrooms.

The report is based on a nationwide survey earlier this year of 250 college and university education school deans and 1,000 of the newest generation of K-5 school teachers (those with three to five years of experience). Among its major finding are the following:

- Only one-third of elementary school teachers reported teaching science every day. One in three said they teach science fewer than two times a week.
- When asked to rate the quality of science education in their schools, only 18% of the teachers assigned it an A, and nearly one-third assigned it a C or D. Only 7% of the deans surveyed said they were "very confident" that elementary school pupils are receiving a good science education. More than half, 56%, said they were "a little confident" or "not confident" at all.
- Only 14% of the teachers surveyed gave an A rating to their preservice training in science. And a strikingly large percentage – 35% – said they rely more on what they learned in their high school science courses than on what they learned in college to teach science. A large majority of both teachers and deans agreed elementary teacher education programs should require more coursework both in science itself and in science teaching methods.
- Only one in 10 teachers said they have participated in programs that offer an opportunity to work directly with scientists and/or engineers on science curricula and other professional development activities. Among those who had, an overwhelming majority said the experience helped them better understand science content, improved their teaching of science content, and bolstered their motivation and enthusiasm for teaching the subject.

Teachers and education school deans overwhelmingly agreed that having students conduct hands-on experiments, form opinions, and discuss and defend their conclusions with others is the most effective way for students to learn science. Both groups also voiced strong support for increased emphasis on inquiry-based science teaching, both in teacher training programs and in elementary school classrooms.

Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement

(Heather C. Hill, Brian Rowan, Deborah Lowenberg Ball, University of Michigan at Ann Arbor, May 2004, http://www-personal.umich.edu/~dball/HillRowanBallMay04.pdf)

This study is the capstone of nearly two decades of research by Deborah Lowenberg Ball and her colleagues on what teachers need to know to teach math effectively. It finds: (1) teachers need a particular type of content knowledge to accommodate students' differing learning styles and aptitudes, and (2) this type of "flexible and expressible" knowledge is positively linked to student learning gains.

Ball's research team designed a 30-item "mathematical knowledge for teaching" assessment that was given to 699 1st- and 3rd-grade teachers at 115 predominantly high-poverty schools drawn from the Consortium for Policy Research in Education's large-scale, longitudinal Study of Instructional Improvement.

The researchers also tested those teachers' students twice – in the fall and spring of the same school year. The results showed greater learning gains for pupils whose teachers also had scored high on the mathematical-knowledge test. They found students got an extra one-third to one-half of a month's learning growth for every standard-deviation rise on their teachers' test scores.

Teachers' scores on the mathematical-knowledge assessment seemed to matter more, the study found, than how much time they spent teaching math during an average school day. This finding applied whether teachers were certified or whether they had taken extensive mathematics or math teaching courses.

Teaching math well, the study concluded, requires not only a solid grounding in the subject and an understanding of how children think at particular developmental stages, but also the ability to apply mathematical knowledge quickly, in ways that make sense to students. A teacher has to be able to "unpack" ideas and procedures to help students grasp the reasons behind them, to pinpoint the sources of the errors their students make, and to choose assessments that show whether students are "getting it," not just making lucky guesses.

Students Continue To Fall Short on National Math and Science Tests

Despite overall gains in achievement over the past decade, most American students still perform below levels considered proficient or advanced on national science and mathematics assessments. In addition, large and persistent gaps in achievement exist between various ethnic/racial subgroups.

Results from the most recent National Assessment of Educational Progress (NAEP) science and mathematics tests show the following:

- Fewer than one in three 4th and 8th graders – and only 17% of 12th graders – scored at or above the proficient level in mathematics.
- In science, roughly one-third of 4th and 8th graders – and nearly half of 12th graders – did not reach even the basic level of competence.
- In both subjects, at all grade levels, very few students (2-5%) performed at the advanced level.
- At all three grade levels, in both mathematics and science, significantly higher proportions of white and Asian students scored at or above the basic and proficient levels compared with black, Hispanic and American Indian/Alaska Native students. In math, for example, fewer than one in 10 Hispanic 8th graders scored proficient or advanced (compared with nearly half of white and Asian students). Sixty percent of Hispanic students scored "below basic," compared with 22% of white and Asian students.

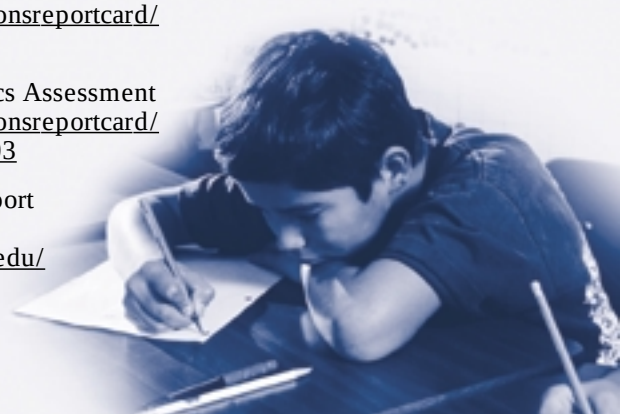
The picture may be even more dismal than the test scores suggest. A recently released analysis by the Brooking Institution's Brown Center on Education Policy found the 4th- and 8th-grade NAEP math assessments are too easy and fail to assess skills essential for success in algebra and higher mathematics.

On both tests, the analysis showed, nearly half of the problem-solving items required little more than 1st- and 2nd-grade arithmetic skills – adding and subtracting whole numbers and basic multiplication. Most of the test items used whole numbers and avoided fractions, decimals and percentages – forms of numbers students must know how to use to tackle higher-order mathematics such as algebra.

Sources:
2000 NAEP Science Assessment
http://nces.ed.gov/nationsreportcard/science/results/

2003 NAEP Mathematics Assessment
http://nces.ed.gov/nationsreportcard/mathematics/results2003

2004 Brown Center Report on American Education
http://www.brookings.edu/gs/brown/bc_report/2004/2004report.pdf



Other Resources

No Time to Waste, a paper prepared by ECS President Ted Sanders for a recent U.S. Department of Education-sponsored conference of higher education leaders, examines the crucial role of college and university presidents in improving science and mathematics education. Among his recommendations: Upgrade and elevate the importance of teacher-preparation programs, and step forward as visible, vocal advocates for the improvement of science and math education at all levels.

The paper concludes with a look at three outstanding examples of leadership and innovation: Purdue University's Department of Engineering Education, the University of Texas at Austin's UTeach Program and the University of Georgia's Middle School Science and Math Teacher Education Program.
http://www.ecs.org/clearinghouse/54/80/5480.htm

New Studies Under Way

The National Research Council, an arm of the congressionally chartered National Academies, is undertaking three studies aimed at exploring how students learn science most effectively, and how it is best taught and tested.

- **Testing**. The focus of this study will be on providing states with practical advice on designing tests that gauge both subject-specific knowledge in science and students' overall understanding of scientific concepts and procedures. Under the No Child Left Behind Act, states are required to begin assessing students in science in the 2007-08 school year. Scheduled completion: 2005.
- **Learning**. This project is designed to increase understanding of how students learn science, with an emphasis on kindergarten through 8th grade. The committee will examine existing research, identify areas in which new research is needed, and determine what that body of evidence suggests about how science subjects should be taught. Scheduled completion: mid-2007.
- **Teaching**. The third study will look at the role that science laboratories should play in the high school classroom. That question has drawn renewed interest among teachers, administrators and researchers recently, partly because of speculation that the new federal testing requirements may compel some districts to scale back classroom experimentation in favor of more direct forms of instruction. Scheduled completion: 2005.

Funding for the three studies – totaling about $3.8 million – will come from the National Science Foundation and the National Institute of Child Health and Human Development.
http://www.edweek.org/ew/articles/ 2004/11/10/11nrc.h24.html.

This issue of *The Progress of Education Reform* was made possible by a grant from the GE Foundation. It was written by Suzanne Weiss, ECS managing editor.

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