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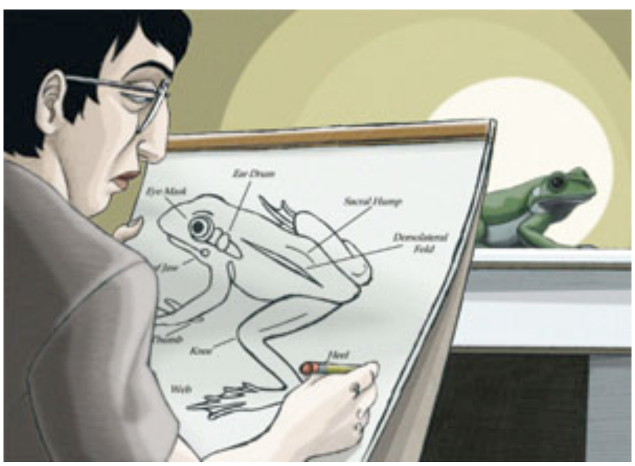
COMMENTARY

The High Stakes in Science Education

Risking the Roots of American Productivity

By Jonathan King

In his 2006 State of the Union address, President Bush created a buzz by calling for new initiatives in science and technology education: "Tonight I announce an **American Competitiveness Initiative**, to encourage innovation throughout our economy, and to give our nation's children a firm grounding in math and science." The plans later unveiled by U.S. Secretary of Education Margaret Spellings contained some positive initiatives. Subsequent budget appropriations, however, have had almost no funds for increasing students' encounters with authentic scientific and engineering processes. The National Science Foundation's **Math and Science Partnership program**, for example, was slashed in the fiscal year 2008 request by nearly 30 percent, from $63 million to $46 million.


—Gregory Ferrand

The aspect of the Bush administration initiatives that has had the single greatest impact on education across the country is mandatory testing for academic proficiency in key subject areas. Under the federal No Child Left Behind Act, standardized tests in science will be added this year to those in reading and mathematics as the law's primary lever for improving student achievement nationwide. Since No Child Left Behind gives great powers to the states to punish, reorganize, or close schools whose test scores do not meet the standard of "adequate yearly progress," test preparation trumps all other aspects of classroom activity. As with other paper-and-pencil standardized tests, the effect of this NCLB testing will be to retard and narrow the quality of science education.

What this will in turn mean for the country as a whole can best be understood by reviewing the steady rise of the American economy over the last century.

In the post-World War II period, the United States has led the world in scientific and technical productivity. Large public investments, through the National Science Foundation, the National

Institutes of Health, the National Aeronautics and Space Administration, and federal agencies such as the departments of Energy and Defense, have produced the scientific and technical advances giving rise to entire new industries: computer hardware and software, new forms of telecommunications, and biomedical breakthroughs leading to new therapies, to name just a few. These advances led to historic rises in the standard of living and quality of life of most Americans. The science and technology underlying these leaps had their origins in the laboratories of America's colleges and universities, joined by a small number of private research institutes and federal laboratories.

What was the educational experience and background of the engineers, computer scientists, physicists, chemists, biochemists, and geneticists who were responsible for these contributions? They were predominantly the product of public school systems, from all regions of the country. In the 1960s, the National Academy of Sciences researcher Lindsey R. Harmon tracked the high school origins of 1958 Ph.D. graduates from U.S. universities. The data revealed that nationwide, public high schools produced the great majority of future Ph.D.s in the physical sciences, social sciences, and biosciences. This was the heyday of U.S. scientific and engineering productivity, and yet there were limited national or state education standards and few standardized, high-stakes promotion or graduation tests.

The remarkable productivity of U.S. public schools stands in sharp contradiction to the claims of Secretary Spellings, or even the National Academies' "Rising Above the Gathering Storm" and other recent doomsday reports about American scientific education that have concluded our public schools are failing.

There is no doubt that students from particular groups, notably minorities and women, have had limited access to high-quality education in the sciences. As a society we are still grappling with these inequalities. But America's public schools have been more inclusive and have produced more productive scientists in the postwar period than the education systems of most other nations. While the British, French, and German systems historically had rigid standardized-examination barriers that excluded large numbers of students from proceeding to advanced studies (or even to academic secondary school curricula), our K-12 public education system opened the door to a broader social and economic cross section of the population.

Were these scientists who graduated from public schools and powered the country's economic ascendency the products of standardized curricula or testing? No. In general, they came out of the learning-by-doing model of education, built on hobbies, laboratory experiences in high school, and science-fair projects. All of these accelerated after the Soviet Union's launch of Sputnik in 1957, thanks largely to congressional passage of the National Defense Education Act. Federal investments through the National Science Foundation and other agencies promoted experience-based laboratory curricula for both elementary school science classes and more-specialized secondary school courses. Passionate science teachers, using different methods, played a critical role in developing curiosity and wonder in receptive students. These students subsequently populated the laboratories of America's colleges and universities, and led the scientific and technical creativity of the following decades.

Scientific productivity is not a standardized commodity. The natural world is incredibly diverse, and, as a result, productive human inquiry takes a great variety of forms. The mathematics needed to describe and understand the motion of glaciers is not the same as that used to calculate the trajectories of asteroids and meteors. The chemistry needed to synthesize new antibiotics is not the same as that used to solve their structure by nuclear-magnetic-resonance methods. Continued advances in human knowledge and technology depend absolutely on nurturing the full spectrum of human intellectual diversity.

But that is not the direction we are taking. Under current national education policy, that curiosity-and-free-inquiry ideal has evolved into something that might be characterized as the "what's the right answer?" syndrome. Let me explain with a personal anecdote.

In our MIT Intensive Biology laboratory course, one of the modules involved observing with a high-powered light microscope the development of a newly fertilized zebra fish egg into a baby fish. Students were able to observe over several hours the remarkable transformation of the symmetrical fertilized egg and blastula into an organism with a head at one end, tail at the other, beating heart, circulatory system, spinal cord, and muscles.

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One goal of the laboratory exercise was to train students to observe carefully. We asked them to draw what they saw. For many, profound questions emerged immediately from their direct observations: How is the head end distinguished from the tail end? Why only one heart, rather than two? What sets the heart beating? Do the eyes actually develop out of the brain, or out of the skin, or from both?

In recent years, I increasingly encountered students whose response was "What should I draw?" My reply was always "Well, draw what you see." Some of the students then asked, "But what should I see?" They were so fixated on getting the right answer that they were unable to observe and draw from their own experience. Often they would search for professional drawings of the different stages, and then wait until they saw features corresponding to those illustrated. They were unwilling to draw images that didn't correspond to "the right answer."

I suspect that some of these students are the products of the increasing emphasis on standardized tests such as the SAT, Advanced Placement exams, and state-mandated high-stakes tests. Preparation for these standardized assessments focuses students, teachers, and school administrators almost solely on getting the right answer—not on asking the right question.

Despite nods to other forms of investment in education, the major NCLB thrust of the Bush administration has been to increase the emphasis on standardized testing. In most cases, this comes in the form of paper-and-pencil tests that can be scored by computer and often are dominated by multiple-choice questions. It is a direction that has been opposed by groups and organizations actually involved and engaged in educating our younger generation. In their recent book, *Collateral Damage*, David C. Berliner and Sharon L. Nichols provide a cogent summation of the damaging and corrosive effects of high-stakes standardized testing on public education.

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Preparation for these tests replaces authentic observation and performance with memorization and "drill and kill" instructional methodologies. Such tests can assess whether students know the names of the parts of a microscope, but not whether they can focus the microscope and assimilate the images they observe.

Pressure on teachers to have their students perform well on standardized tests sharply reduces the classroom role of experimentation, the design and construction of projects, field trips, and related encounters with natural processes. By shifting emphasis from direct encounters with natural phenomena to test preparation, high-stakes exams will become a major factor alienating students from science and technology and turning science education back to pre-World War II, rote-learning modes.

Neither sociologists, neuroscientists, nor educators have been able to identify the variations in early experiences that lead to different flavors of human inventiveness. The current administration's education policies, proposing that science courses in America's high schools and colleges approach their material in the same standardized manner, can only impede the skill and talent development our society and our young people need.

To increase the competency, literacy, and skills of our students, we need to increase their exposure to active, inquiry-based classrooms. This is what was called for in the seminal "Science for All Americans" report of the American Association for the Advancement of Science. Increasing pressure from the Bush administration to replace authentic scientific and technical education with test-driven initiatives will sharply reduce the productivity and creativity of our future scientific workforce and truly place the future of the nation at risk. Scientists and educators need to join together to resist this turn backwards.

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