Washington Internships for Students of Engineering

Ensuring America's Competitiveness:

Strengthening K-12 Education

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Executive Summary

Frontiers of the mind are ahead of us, and if they are pioneered with the same vision, boldness, and drive with which we have waged this war, we can create a fuller and more fruitful employment and a fuller and more fruitful life. Vannevar Bush, July 25, 1945.

We are approaching a precipice: the coming shortfall of workers with technical backgrounds. Fareed Zakaria, columnist for Newsweek magazine, asked in the question that many policy makers, industry leaders and academics have been asking. In the face of growing global competition, with increasing numbers of engineers graduating in countries like India and China, and with a shrinking proportion of undergraduate students choosing to study engineering and the physical sciences in this country, will we as a nation have the capabilities to innovate, to produce and to participate in an economy reliant on technology?[1] Seminal innovators like Andy Grove, co-founder of Intel, think, "America … [is going] down the tubes." As Zakaria points out, the concern lies in "the erosion of science and technology… in education," an issue pinpointed in the 2005 National Academies report, *Rising Above the Gathering Storm*, and which President George W. Bush singled out in the 2006 State of the Union address. The state of the American economy, and its consistent and persistent growth, would indicate that we are maintaining our course. Our productivity is steadily climbing, our system of higher education is capable of producing the finest people, and the research and development establishment in America--the collaboration between government, academia, and the private sector--is unmatched the world over, and succeeds in attracting the world's talent.

But in reality, we should be very scared. The world and its economy rely on technology, and the complexity of technological systems is increasing. We expect careers in science and technology to increase by 70 percent by the year 2012. At the same time the talent pool overseas is increasing in number and foreign investment in R&D is also showing growth. Meanwhile, quietly, with minimal attention, our students in K-12 education are losing ground. Without the next generation of innovators, we risk losing our competitiveness.

We need a creative and motivated technical workforce to maintain our leadership in science and technology. "Precollege STEM education is the foundation of that leadership—it must receive our highest priority as a Nation."[2]

The American public does not believe, or at least does not seem to acknowledge, that the system charged with preparing the next generation of innovators is heavily compromised. A third of our public schools are totally dysfunctional, and falling performance suggest that something fundamental is occurring. While grade 4 and 8 test scores indicate that students' scores are increasing, the flat 12 grade average score suggest that instead we are not retaining enough interest in technical subjects. This perhaps explains low number of college entrants interested in engineering. While we sit on our hands, looking at the declining number of American STEM students, nations around the world see opportunities in the growing knowledge economy and look for ways to take advantage of and find the best use for human potential. The US must act now to improve its K-12 educational system.

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[1] Zakaria, Fareed. How Long Will America Lead the World? *Newsweek.* 2006.
[2] National Science Board. 2006. *America' Pressing Challenge-Building A Stronger Foundation.* National Science Board.

Our students' drive to study math and science must outweigh their hesitation. To inspire our students to commit to the hard and consistent work necessary to master vertical subject matter—subject matter where following concepts rely on mastery of past concepts—we must look to teachers. There is a deeply concerning shortage of qualified STEM teachers in the American education system. A dismal number of them are even qualified in the subjects of math and science, especially in 7th and 8th grades when our students are most in need of encouragement and motivation.

There is a shortage of teachers because students who study math and science find better jobs outside of education. Studies even suggest that those who enter teaching professions, on average, have lower academic scores than those who do not go into teaching, sadly validating the phrase, "Those who can, do, those who can't, teach."

What America Must Do

To correct the problem, we should find ways to:

Improve the skills of current teachers.
Recruit students majoring in STEM subjects to teaching careers
Challenge students through more difficult courses
Improve STEM curriculum to make it more effective, relevant, and captivating.
Involve the current American technical workforce in training new generations of innovators.

Recommendations for Action on the Federal Level:

1. Congress should pass and fund the initiatives of the PACE legislation directives for K-12 education.

The Protecting America's Competitive Edge in Education and Research Act is designed to attract the finest minds to the teaching profession of the next generation of the finest minds, and invests in improving the technical capabilities of our current K-12 math and science teachers.

It increases the financial incentives for America's talented students to commit to education, thereby improving the most powerful indicator of student success, the level of teaching. We can hope to thereby increase the number of students with instructors who have Bachelor's level knowledge in a technical field while also promoting the spread of research-based, subject specific teaching tools.

Master's level programs in Mathematics and Science education would offer yet another way to augment our current teaching resources by serving as experts who could help to locally train and assist our teachers; hopefully they would prove to be powerful for the professional development of future educators.

In addition, if the nation's public education system were to triple the number of students both taking and passing the AP and IB exams, trends indicate we would see a significant jump both in the number of students graduating from college, and in the number of students prepared to pursue engineering and science majors.

This bill, as written, has 62 cosponsors in the US Senate, indicating the amount of support it currently receives, and support should continue.

2. Develop standards for programs that provide alternative means to teacher accreditation. Fund the creation of pilot federal programs to demonstrate effectiveness.

Our current workforce is the pride of this nation's economy, and we should do more to encourage those who have helped to make our nation technologically competitive, to help make our education system stronger than ever.

The federal government should lower barriers to professionals wanted to teach by promoting programs that accredit teachers by other means than traditional certification programs.

First, Congress must commission research on effective ways to produce competent teachers with dedicated mentors and support.

Leaving the selection of qualified candidates to the program directors, the federal government should pay program fees for career scientists and engineers seeking to complete alternative credential programs, reducing the financial burdens such professionals would incur.

3. Support the workforce of science and engineering professionals in education the next generation of by creating partnerships between education institutions and the private sector and national laboratories

Using the idea behind apprenticeship programs, we can see the rationale for recruiting career professionals to partake in classroom instruction in technical subjects.

The federal government should support such programs by working with state and local governments to create partnerships between education institutions and the private sector and national laboratories.

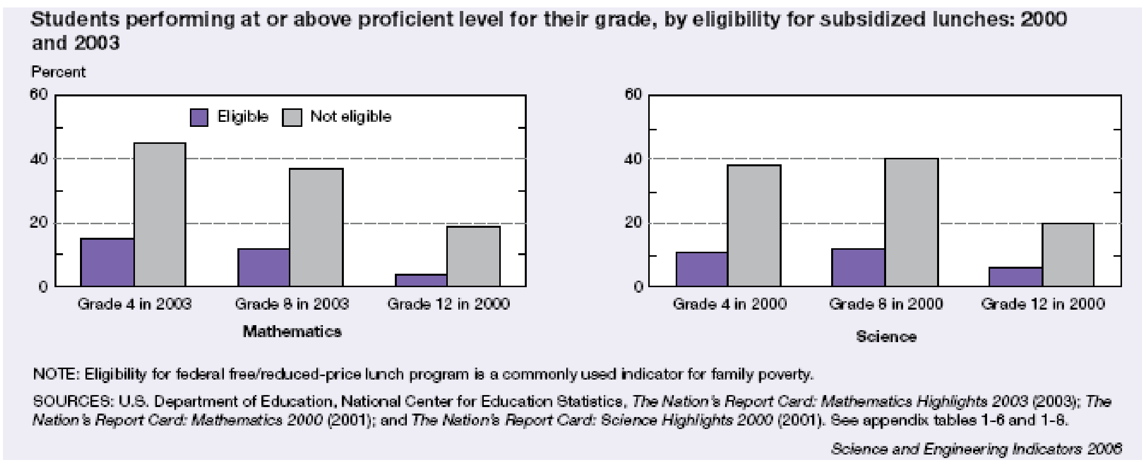
First, congress should mandate that employment opportunities be made available for qualified science and engineering professionals with a teaching degree.

Secondly, Congress should provide financial incentives—tax credits or funding to corporations that support employees in pursuing training to become teachers and who teach in either a sabbatical format or in a part-time capacity. Similar sanctioning within the national laboratory infrastructure would offer access to additional skilled resources.

Contents

Defining the Issue

America faces a big problem. Improvements in technology in virtually every sector of the economy have changed the way the world does business and are allowing greater competition between growing numbers of players. The demands of increasing complexity in and reliance on technology in the economy call for a talented workforce with technical knowledge and skills. However, in our educational system, we have lost sight of the importance of science and technology. To maintain our global science and technology leadership, America needs drastic improvements in both the number and the quality of Science, Technology, Engineering, and Mathematic (STEM) students in this country. Indeed in the coming decades, to ensure that Americans remain as competitive as they have been, it is imperative that they be given the premium skills necessary not only to participate in the growing knowledge-economy, but to make informed decisions and contribute to the democratic process that guides our nation.



Fewer students are prepared for science and engineering majors in higher education. The most striking indication of our failure is the number of students taught by K-12 teachers with little experience in the subjects they teach. The intent of this paper is to present the case that science, technology, engineering and math (STEM) education in our K-12 system is in dire need of overhaul and to discuss policy actions designed to accomplish that task. It also behooves us to simultaneously investigate the motivation for students to study STEM and to ensure that curriculum attracts both teachers and students to explore the exciting and ever more crucial role that science, technology, engineering and mathematics play in our lives. Engineers and scientists, through innovative use and creation of technology, play an ever-increasing role in driving forward the economy, and for the last 5 decades, American research and development has been a dominant force in that cycle of innovation, production, and application. We should look for ways to apply that cycle to K-12 education and accomplish the following: to train teachers with STEM expertise, to teach more challenging course material designed to fit the way students learn math and science, and to involve our technology workforce through opportunities for professionals to be involved in educating the next generation of innovators.

How Far Reaching Are the Consequences?

The October, 2005, report from the National Academies of Science, *Rising above the Gathering Storm* (RAGS), addresses the issue that perhaps as a nation, we are in danger of losing our competitive edge. Though there have been other voices sounding the alarm, RAGS in particular has generated a lot of attention and has been effective at drawing the attention of the public at large. The report calls for immediate action, and notes that it is imperative to change course in order to ensure that America does not loose its leadership in technology and remains in a position to benefit from the next wave of innovation. Most alarming is students' poor interest and quality of performance in K-12, and without immediate action to improve teacher quality and motivation in our students, American innovation and research and development--which rely on a creative and talented workforce—are at risk. While America appears strong by economic measures, the American workforce is silently approaching a precipice. As Dr. William Wulf, President of the National Academies of Engineering, has said, "look at the derivatives," at the rates of production, and we see the impending crisis. Finally the public is catching on.

Another voice bringing the issue to light is Thomas Friedman. He has also done his part to describe the issue of global competitiveness in his book, the *World is Flat*, depicting the world as a place where the "playing field is being leveled."[3] In this flattened world, says Mr. Friedman, companies large and small, and especially individuals, have been newly empowered, allowing people to "plug and play", to use a growing world wide technical infrastructure to compete even with large companies in the global knowledge economy[4]. This particular infrastructure includes the standards, hardware, and software that will allow individuals of diverse backgrounds—non-Western and non-White—to innovate on a level with people in developed nations with many resources, like the US and Japan[5]. It will allow jobs to move where the human resources are richest, or, as Intel Spokesman Howard High has said "Where the smart people are[6]."

Throughout the end of the last century, the US has been home to highly trained scientists and engineers capable of innovating disruptive technologies. In *The World is Flat*, the technologies that Mr. Friedman lists as creating flattening forces were developed in the United States. PCs were invented and widely distributed first in the US, and the Internet and its protocols got their start here. It was when the US company, Netscape, created the Web Browser, and went public, that the world saw the potential for innovation and profit through the ability to be interconnected.[7]

The success of Americans in technical fields has been no accident; through investment by the private sector and by the government, working closely with the world's strongest institutions of higher education, this nation has created a workforce with the skills, the resources, and the opportunities necessary to innovate. What follows is a discussion of some of the resources that have helped established the US as the highest ranking nation in economic competitiveness, and that also represent what we as a nation stand to lose, if we do nothing to correct the quiet crisis.[8]

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[3] Friedman, Thomas. 2005. *The World is Flat.* New York: Farrar, Straus and Giroux. P. 7
[4] Ibid.
[5] Ibid.
[6] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies. In the perspectives section of the Executive summary.
[7] Friedman, Thomas. 2005. *The World is Flat.* New York: Farrar, Straus and Giroux.
[8] IMD World Competitveness Yearbook. 2006. Available at: http://www01.imd.ch/wcc/ranking/

R&D expenditures and share of world total, by region: 2000

NOTE: R&D estimates from 80 countries in billions of purchasing power parity dollars.

SOURCES: Organisation for Economic Co-operation and Development, *Main Science and Technology Indicators* (2004); Iberoamerican Web of Science and Technology Indicators, http://www.ricyt.edu.ar, accessed 1 April 2005; and United Nations Educational, Scientific and Cultural Organization (UNESCO), Institute for Statistics, http://www.uis.unesco.org, accessed 7 April 2005. See appendix table 4-57.

Science and Engineering Indicators 2006

Higher Education in the United States

Institutions of higher learning are crucial as a foundation for research and development because they bring together the world's most talented students with the highest quality researchers, and offer a hotbed for creative and bold experimentation. In the process, well-trained students can learn about exciting, cutting edge technology, and bring that expertise to the workforce. Of the world's 50 top universities, 37 are located here in the US.[9] Scientific publication in this country rates above that of any other nation, and US publications account for over two fifths of all citations.[10] The basic research conducted at US colleges and universities accounts for nearly half of the basic research nationwide, and in addition, academia performs a third of the nation's basic and applied research.[11] The innovative force of our nation's institutions of higher learning is evident, given the fact that the peer-review system in science is efficient at weeding out non-competitive academic research, so that such basic research must necessarily be cutting edge.[12]

The US colleges and universities have also produced the finest talent. Doctoral training is the collaboration of researchers and graduate students in an apprenticeship model in which the research skills of the faculty are passed to the student. For decades, US institutions accounted for 20 percent of the world's science and engineering doctorates, and the US custom of providing

[9] Institute of Higher Education, Shanghai Jiao Tong University. Academic Ranking of World Universities. 2005. Available at http://ed.sjtu.edu.cn/rank/2005/ARWU2005TOP500list.htm

[10] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A). Table 5-23.

[11] Ibid.

[12] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.

myriad postdoctoral positions allows continued pursuit of research goals after obtaining a doctorate.[13] The people who hold doctorates play a crucial role in teaching and training students, and in stimulating and helping to produce innovation.[14] An important aspect of the success of US institutions is their ability to attract foreign talent as well, ensuring greater diversity. We dwarf other nations in the number of foreign born students educated in this nation's higher educational system, and as many as 70 percent of foreign doctorate students have plans to stay in the US following graduation.[15] The level of foreign participation is an indication of the attractiveness of our academic research community. Foreign nations, recognizing the value of an education in this system, provide support to students attending the US institutions and invest in job infrastructure to entice students back.[16]

With all of the advantages of the US system, it is both encouraging for the sake of global growth and troubling because of growing competition, to see the rest of the world rush to give their workers the skills they need, such as English language engineering classes, and to see the increase in number of peer reviewed publications from other developing nations.[17] In 2003, international students earned 38 percent of the US-awarded S&E doctorates and 58.9 percent of the engineering doctorates.[18] US institutions of higher learning are strong and contribute to our nation's ability to compete by supporting breakthrough basic and applied research and by training the next generation of innovators. However, in research fields crucial to technological innovation, our tax dollars are no longer going to train enough of our own students.

Federal R&D Support

Much of the research done at American research universities is funded by the federal government, including 56 percent of public university science and engineering R&D and 74 percent of private university R&D.[19] Academic R&D funding made up 14 percent of the unmatched R&D budget in the United States. At a time when many governments around the world are beginning to follow the US's example and increase R&D investment, the US public and private sector spent $285 billion on R&D in 2000, or 39 percent of the world's R&D expenditures, of which 24 percent came from the federal government.[20] The federal commitment to R&D has spawned an amazing array of commercial technology including Velcro, the microwave oven, and the Internet.

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[13] National Research Council. 2002. *Attracting Science and Mathematics Ph.D.s to Secondary School Education*. National Academies Press.

[14] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A).

[15] Ibid.

[16] Friedman, Thomas. 2005. *The World is Flat.* New York: Farrar, Straus and Giroux.

[17] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A). Table 5-23.

[18] National Science Foundation. 2004. *Science and Engineering Doctorate Awards: 2003* (NSF 05-300). Arlington, VA: National Science Foundation. Data are available at *http://www.nsf.gov/sbe/srs/nsf05300/tables/tab3.xls*.

[19] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A).

[20] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: National Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A).

An astonishing 73 percent of patents filed in the US benefited from public funding as a resource for the projects.[21]

As private sector basic research investment has dwindled, the national laboratory system, comprised of 700 laboratories, has been asked to play a more active roll in conducting cutting-edge research.[22] Funding for these national laboratories constitutes about 35 percent of the total federal R&D budget.[23] Though the research profile of the laboratories may contain the right mix of basic science and applied technology research, there are large discrepancies in funding across disciplines, as, over the last decade, funding increases for biomedical research, through the National Institutes of Health, has vastly outpaced that of other fields.[24] The vast improvements in biotechnology over the same time period suggest that increasing funding to other disciplines in a similar manner would achieve analogous results.[25]

Federal funding for the national laboratories is also intended to direct innovation in the area of national defense, and spending on science and technology is also imperative for ensuring national security. In a global economy that increasingly relies on technology and promotes creativity and innovation, it is equally important to anticipate new creative security threats and to protect against them. To this end, the national laboratories will rely on new generations of scientists and engineers to develop the security measures that will effectively protect our country against any growing threats, including working to improve energy technologies that will decrease our dependence on volatile regions of the world. The demand for a qualified science and engineering workforce will only grow, as innovation creates marketable technologies, as well as enable greater security through reliance on technology, and it appears that the demand will soon outstrip the US supply.

The Private Sector

America is characterized by a culture of inventiveness and risk taking.[26] This scrappiness is embodied in a US private sector that has always permitted bold experimentation and development of radical technologies. In the past, there have been examples of private sector basic research ventures that have yielded incredible technologies, for instance, Bell Laboratories and Xerox. Venture capital spending in 2002 was down to one fifth of year 2000 levels, but the ability to raise funds is increasing, suggesting more risk taking in high tech fields.[27] This is a welcome sign since the tech boom and bust of the nineties. While the tech bubble brought technical careers to

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[21] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.
[22] Ibid.
[23] M. Crow and B. Bozeman. Limited by Design: R&D Laboratories and the U.S. National Innovation System. Columbia University Press: New York, 1998, pp. 5-6.
[24] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.
[25] Office of Science and Technology Policy. Domestic Policy Council. 2006. *American Competitiveness Initiative: Leading the World in Innovation*. Washington DC: Domestic Policy Council.
[26] Zakaria, Fareed. How Long Will America Lead the World? *Newsweek*. 2006.

[27] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.

light, it also contributed to the idea that a career in science and engineering is unstable.[28] Tax incentives are structured to increase the levels of R&D spending in the private sector, but the private sector relies on the creativity of the workforce to turn R&D into profits. Alarmed at the low numbers of scientists and engineers graduating from college, and the lack of focus on science and engineering as a critical component for innovation success, some of the largest business organizations in the country are also announcing their concern that there will not be enough qualified technically trained US workers in the coming decades.[29]

The combined supply of science and engineering graduates with 7 years experience in low-wage countries outnumbers that in high-wage countries, including the US. These graduates represent both opportunities and competition for Americans. Jobs will increasingly go overseas to take advantage of these workers: 33 million in 28 countries, to 7.7 million in US, 15 million in 8 high-wage countries. While companies look to overseas call centers, manufacturing, or R&D structures that take advantage of lower wages to cut cost, employment for highly trained scientists and engineers in this country is showing promise.[30] Wages for college graduates have risen faster for those with more technical training, suggesting the value of workers who are in a position to innovate in technical fields.[31] However, as access to knowledge in the research and development communities overseas has improved, wages in those countries for highly skilled workers have also shown growth. In addition to solid technical training, workers in a flatter world will need language skills, the ability to interact with different cultures, to manage teams, to problem solve, to communicate effectively, and most of all, the motivation to apply those skills to compete. To prepare the next generation of US citizens to participate in the next wave of innovation, the acquisition of technical, communication, and cooperation skills must be the backbone of the American educational system.

The Next Generation of Americans Needs Education

We Americans stand to lose our competitive edge in technology and innovation if we do not better train our school age population.[32] As an illustration of our reliance on these fields, from 1890 until the middle of the last century, technology accounted for 85 percent of the growth in US income.[33] After the end of World War II, America forged ahead in science and technology and the US government invested in and trained a competent workforce on the GI bill, an investment in human capital that perhaps remains unmatched.[34] The availability of skilled workers in America has enabled us to build upon our success and develop technologies and products that have changed the face of the world. With more people and more nationalities as global players, more people will able to afford a higher standard of living, consumption of goods is bound to rise and huge markets will enter into the world economy. While this is good news for producers and many of the world's citizens, the situation only stands to benefit those individuals and companies who are prepared to compete. Americans have been the best prepared population

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[28] *Electronic Engineering Times.* April 10, 2006. Interview with Geoffrey Orsak, Professor at…
[29] US Chamber of Commerce. 2005. *Tapping America's Potential: Education for Innovation Initiative.* Available at: http://www.uschamber.com/publications/reports/050727_tap.htm
[30] Ibid.
[31] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.
[32] Ibid.
[33] Ibid.
[34] US Chamber of Commerce. 2005. *Tapping America's Potential: Education for Innovation Initiative.* Available at: http://www.uschamber.com/publications/reports/050727_tap.htm

in the past, but signs suggest that our citizens will not be as successful in the future. We must act now to improve our education system so that Americans can participate as the next generation of innovators.

Recognizing this, much of the world has looked to the U.S. as a model and has begun to also invest in STEM education and in research and development. By encouraging students to pursue STEM fields, countries like India and China produce capable high tech workers. As the number of highly-educated personnel grows overseas, so too will their capacity for innovation, and we will see increasing competition from motivated and talented populations. The effect is evident; Friedman paints a convincing picture and points out that the world is bound to only grow flatter. More innovation will be to our benefit, but with more players vying for jobs in a knowledge economy in a flatter world, participation will increasingly be contingent upon our own ability to innovate. As innovation is an innately human quality, to continue to support and foster a culture of innovation, Americans need the finest minds and the most explosive creativity.

Background

The US has a history of rising to a challenge, and has on several occasions reacted to adversity, real or perceived, by investing in education. As mentioned above, after World War II, the Serviceman's Readjustment Act of 1944, the GI bill, was the federal government's investment in the reeducation of veterans to prepare them for work here in the US, to fill the shortage of trained personnel. When the Soviet Union successfully launched the first satellite, Sputnik, in 1956, the United States responded to the challenge of a space race by investing in the public education system through the National Defense Education Act in an attempt to train more scientists and engineers. The Cold War was a constant reminder that technology and science were vital to national security. Soon after Sputnik, President John F. Kennedy made science and engineering a national priority, heavily funded the national laboratories, and inspired a generation of scientists and engineers when a man walked on the moon on July 21, 1969. Another scare happened in the 1980s when it became apparent that Japan was making high-tech research and innovation a priority. Past investment in education may explain the surge in successful engineers and scientists, waves of research and innovation, and the 60 percent of Fortune 100 CEOs with science and engineering degrees.[35] Others educated during those times are the strength of our research universities. The quality of innovation in the US rests in part on the investment in science and engineering education spurred by challenges like Sputnik and global competition.

In contrast, Friedman says emphatically that today we are not "investing in our future and preparing our children the way we need to be."[36] The US has long held the view that education is a public good, and we have stressed that our children need to be competent to compete and cooperate on the global scale, to contribute to and benefit from a knowledge-based economy. Today, members of academia, government and industry, as well as the public, have expressed concern over the state of the K-12 education system, but they feel that, for the nation on the whole, the coming shortage of a well-trained workforce lies beneath the radar.

In "Rising Above the Gathering Storm," the National Academies likens the situation to the folktale of the frog and the pot of water. Put a frog into a boiling pot and it will jump out

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35 Council on Competitiveness. 2005. *Innovate America: National Innovation Initiative Summit and Report*.
36 Friedman, Thomas. 2005. *The World is Flat.* New York: Farrar, Straus and Giroux.

immediately. A frog that sits in a pot of water as the water heats will not react and will instead cook.[37] Without a galvanizing event, we are in danger of remaining complacent, and without improvements to the K-12 education system, our children will no longer have the ability to compete. While only a part of the puzzle, the single most important resource in the future will be the creativity, hard work, and drive of an educated and prepared public.

We must look to the beginning of the education pipeline, the K-12 system, and we must act to correct the waning interest in science and engineering, limited K-12 preparation in those subjects, and high attrition rates, in high school and beyond.

Fewer Interested Students

The number of jobs requiring technical training is growing at five times the rate of other occupations, yet the average age of America's S&E workforce is rising,[38] and we will soon lose many of the minds and much of the knowledge that has helped to get us this far. At the same time, the average number of entrants is static or declining for disciplines outside of the biological and social sciences.[39] The US recently ranked 16 out of 17 developed nations in the percentage of university students studying engineering, and 20th out of 24 nations when considering all 24-year olds.[40] Today, we manage to prepare and inspire only 6 percent of our students to go into engineering. Out of the 1.1 million high school seniors in the United States who took a college entrance exam in 2002, just under 6 percent indicated plans to pursue a degree in engineering — nearly a 33 percent decrease in interest from the previous decade.[41] When compared with 12 percent in Europe 40 percent in China, and 20 percent in Singapore, we begin to see indications of the coming crisis.[42]

Poor preparation

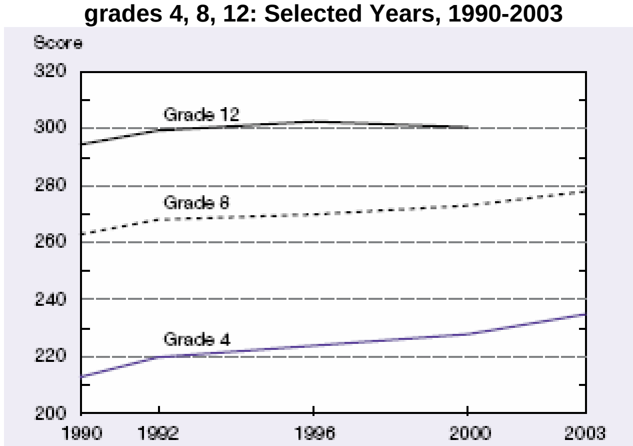
In addition to lower interest in pursuing S&T studies and careers, American students are not well prepared for challenging science and engineering curriculum.
In the Programme for International Student Assessment (PISA) of 15-year-olds' math problem-solving skills, the United States had the smallest percentage of top performers and the largest percentage of low performers compared to the other participating developed countries. US 15-year-olds rank near the bottom in international studies in using math to solve practical problems.[43] US students scored 24th out of 25 countries on the math portion of PISA and only slightly higher

[37] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.
[38] Council on Competitiveness. 2005. *Innovate America: National Innovation Initiative Summit and Report*.
[39] Ibid.
[40] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: Nationl Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A).
[41] Richard J. Noeth et al., Maintaining a Strong Engineering Workforce: ACT Policy Report(Iowa City: ACT, Inc., 2003). Available at http://www.act.org/path/policy/pdf/engineer.pdf.
[42] US Chamber of Commerce. 2005. *Tapping America's Potential: Education for Innovation Initiative.* Available at: http://www.uschamber.com/publications/reports/050727_tap.htm

[43] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies.

in science scores. Although there was steady improvement in mathematics test scores from 1990 through 2005, only 36 percent of 4th grade students and 30 percent of 8th grade students who took the 2005 National Assessment of Educational Progress (NAEP) performed at or above the proficient level in mathematics.[44] The results of the science 2000 NAEP test were similar. Only 29 percent of 4th grade students, 32 percent of 8th grade students, and 18 percent of 12th grade students performed at or above the proficient level. Only about a third of 4th and 8th grade students scored at the proficient level for their grades in mathematics and science, while that number is even less for 12th graders.[45] Long before choosing science and engineering in college, interest in and preparation for research or technical careers is affected in middle school, when pre-algebra and algebra are taught. If a student performs poorly in a math class in middle school, the student is effectively shut out from research careers. Science and math ability is fundamental to STEM undergraduate education and technical careers, and without students who learn fundamental knowledge and skills, we cannot expect to maintain our high quality technical workforce.

Average mathematics score of students in grades 4, 8, 12: Selected Years, 1990-2003



SOURCES: U.S. Department of Education, National Center for Education Statistics, *The Nation's Report Card: Mathematics Highlights 2003* (2003); and *The Nation's Report Card: Mathematics 2000* (2001). See appendix table 1-5.

Science and Engineering Indicators 2006

High Attrition Rates from Scientific and Technical Subjects

In addition to low interest coming out of high school, students majoring in these subjects in college have the highest attrition rates when compared with their peers in other majors. Particularly troubling is the rate of attrition amongst women and minority students, suggesting members of these groups are discouraged long before joining the work force. Once in college, any lack of preparation quickly meets formidable opposition as competitive classes discourage ill-prepared students through the introductory courses where the attrition rate is extremely high.

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[44] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies. Proficiency was demonstrated through competence with "challenging subject matter".

[45] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: Nationl Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A).

While America is forgetting the lessons of the past, other nations are remembering them and speeding to increase the number of engineers and scientists who graduate from universities. A recent Duke University (Gereffi, G., et al. 2005) study suggests that while China currently graduates 350,000 engineering students per year, they are pushing to raise that number to 600,000. India graduates approximately 100,000 engineering students a year and opens new universities with technical education at an impressive clip.

In our educational system, we have lost sight of the importance of science and technology. The perceived shortfall of both quality and quantity of science and engineering students entering high school has been attributed to low quality teaching and weak curriculum. We are faced with the tasks of improving the quality of science and mathematics competency amongst our K-12 students and also boosting the interest and motivation to study these subjects. To do so we will need to better prepare our teachers to teach technical subjects and simultaneously improve curriculum, in order to introduce students to current technology in a relevant way. Better teachers and curriculum must stimulate students and provide them with opportunities early in their studies to discover the importance of science, technology, engineering and mathematics in today's world.

Key Conflicts and Concerns

Education, Tech Education is the key to creating future leaders. [Institutions must teach] research and enquiry, innovation, use of high-technology, entrepreneurial leadership and moral leadership.—Indian President A.P.J. Abdul Kalam, speaking at the University of Mumbai

There seems to be consensus that the future competitiveness of the nation lies in the hands of the next generation of engineers and scientists, and how well they succeed at continuing to innovate will determine our position in this global technological economy. In order to ensure the next generation of engineers and scientists receives the preparation needed for fast-paced and wildly expanding collaboration and competition, the K-12 education system in America must help to shoulder the dual tasks of better preparing our students and increasing interest. While there have been some suggestions as to how improve the system, it bears discussing other aspects of the problem.

If the US government follows the suggestions of RAGS, it must also confront the alternative view given in RAGS itself. We owe much of our concern to discussions of averages: national average scores, average performance of teachers, average money spent per student. As RAGS points out, there are those who would contend that perhaps the issue lies instead in the disparities in the educational system. There is a strong correlation between abundance of school district resources and socioeconomic status. In this country, students in many fortunate districts often outperform foreign students in math and science, while students in low-performing areas often perform on par with students from "scarcely developing countries".[46] Conditions in low-performing areas pose physical challenges similar to those in developing countries: large class sizes, dilapidated buildings, inadequate funding, and a host of problems that accompany poor settings. If education is a public good, hand in hand with talk of improvements in the public education system must come discussions of how that public good can be equally delivered to all citizens. It is in the best interest of the nation to attack the deeply rooted forces that create physical pockets of society in which such dismal educational conditions can exist and persist. Some suggest that because they are less controversial, education reforms are on the table instead reforms that address the deeper forces.

The United States spends more than $455 billion annually for elementary and secondary education.[47] If we as a nation are to spend more money on our educational system, it is important to ensure that the system is efficient and fair. In a real way, the state of public education in some poor rural and urban areas acts as both an incentive and as a deterrent to potential teachers. When the opportunity arises to make a difference as a teacher in these areas, or when a potential teacher has learned enough about the discrepancies in the system to engage herself in the process, the desire to correct the situation, to help by touching hundreds of lives over the course of a career, can act as a powerful moral incentive. At the same time, the very same conditions can turn away competent teachers from low-performing areas to schools and districts where they may feel their talents are better utilized. As an example which will be further discussed below, legislation

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[46] National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. October, 2005. *Rising above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: The National Academies. Alternative view box

[47] U.S. Department of Education, National Center for Education Statistics, Revenues and Expenditures for public Elementary and Secondary Education: School Year 2002–03(Washington, DC: U.S. Department of Education, May 2005). Available at http://nces.ed.gov/pubs2005/2005353.pdf.

currently in the Senate Committee on Health, Education, Labor and Pensions, would fund STEM students to pursue a teaching credential and commit to 5 years of teaching, and we must ensure that their education benefit both students in low performing areas as well as those in high performing schools. The legislation would stipulate that recipients of additional funding awards spend the 5 years teaching in schools that satisfy characteristics typical of low-performing school districts, but we must also be careful to recognize the difficulty of teaching in these areas and the possibility that these teachers may turn to other careers once their commitment is fulfilled. We cannot know where the next great innovators will get their starts. If we talk about increasing the supply of instructional resources, we must be sure that the systems that employ our new teachers can also help our students overcome social forces that may stand in the way of quality education. If our nation is a meritocracy, but educational conditions fail to prepare students to join the ranks of elite, then we lose out by not cultivating one of our nation's greatest resources, the source of our greatest potential.

Still, despite the charge that education reforms are often suggested in lieu of more sweeping policies, improvements in our educational system are indeed central to improving the number and preparedness of science and engineering students.

More central to the problem of educating engineers and scientists is the issue of motivation. To study engineering and science fields requires hard work and many long hours of studying. The best positions in engineering professions go to those most qualified and becoming qualified requires being proficient at vertical subjects like math, where the next topic demands mastery of previous material. This means a student often cannot make up for lost time, and once behind in math, remains behind. American students are losing ground between 4^{th} and 8^{th} grades, indicating that one year of poor performance or poor teaching is enough to drive many of these students away from math.

Additional social norms say that being smart is often a social detractor. Even more frustrating is that this affects girls more than boys, especially in science and math education. These are frustratingly powerful forces, and have been studied extensively and continue to cause controversy. Take Dr. Lawrence Summers' comment in his campus wide address as president of Harvard. While lamenting the small percentage of women in engineering academia, he suggested it may be attributed to a fundamental difference between women and men.[48] Other anecdotal evidence includes a math class of gifted boys and girls, split evenly, who were working with a mentor to choose a research topic for the semester. Despite excellent abilities, by the end of the class, nearly the entire population of girls had dropped out. According to the teacher, the one effect causing the attrition was peer pressure on the girls to avoid the label "geek." Not knowledge, skill, achievement, encouragement, or progress was a factor, most of the girls performed excellently. But, they felt that participating was detrimental to their social standing, their ability to have and keep friends, to be invited to events, and even caused them to be shunned. Similar peer pressure effects boys as well, indeed look anywhere in popular culture and the "tech nerd" is a typical scapegoat, while the "popular kids" rarely rely on intelligence for their popularity. Such is the adolescent social scene, but this pressure certainly contributes to curbing motivation for studying math and science.

Furthermore, the pace of technological advancement leads some to believe that innovation is in danger of being taken for granted. What is certainly true is that within the space of twenty years, analogous devices that perhaps previously invited tinkering are now so far advanced that it is difficult to ask, "How does this work?" While a crystal radio used to be a fun project that gave a

[48] http://en.wikipedia.org/wiki/Sex_and_intelligence#Controversy

good idea of how a commercial radio worked, an iPod is not a particularly transparent device. While the internal combustion engine of a 1970s Volkswagen Beetle lends itself to experimentation, the technology and science in a 2006 Jetta prohibits tinkering for the sake of playing. What effect can this have on inspiring students to participate in technical fields? The burning interest that drives a new student to study the technical aspects of a new device is tempered when it is difficult to fathom the apparent ease with which technology is delivered to the user. The issue is that technology is increasingly hard to understand, which of course indicates that through innovation we are taking advantage of complex systems and tools, but it is perhaps prohibitive to prospective students.

Another aspect of the motivation behind choosing engineering or science as a career is the perceived opportunities awaiting the graduating engineer. The image is that engineering is, in the words of Dr. Geoffrey Orsak, a "back-office profession."[49] An engineer is far removed from the end customer. In one sense, their job is to creatively meet the demands of consumers with whom they have little contact. Not only does this mean that a typical student never knows what an engineer does, but it also pits the profession of engineer against others such as doctor, lawyer, or businessman, where motivated students see the potential to personally affect the community, and perceive that the work of engineers is less tangible. Also, the persistent bad taste of the 90s technology bubble may give the idea that employment opportunities for emerging engineers are fading when in reality, more and more companies are recognizing the value of an education that stresses problem solving and analytical skills and tools.

The previous issue, the image of the engineering field, is of particular concern. The engineering profession does not accurately reflect society as a whole. Women and minorities are underrepresented in science and engineering careers. This has an effect on recruiting students in these groups to the fields of science and engineering. The rigor and competition in these subjects, along with the impression that careers in science and engineering are underappreciated, are already enough to deter many students. Additional pressure comes from being one of only a few women in class and confronting the fact that she is likely to remain underrepresented in the future. The innovators of the future will benefit from as many opinions and ideas as they can possibly create, and it takes no imagination to see that inclusion of all groups will enable us to gain more perspective, gather more ideas, and take advantage of the creativity of a much broader section of our students. This is a major problem and it bears addressing in any proposed policies.

It appears to be as Mr. John Voeller, CIO/CTO of Black and Veatch, said, that a child will not study science and engineering unless the drive and curiosity outweigh the hesitation. The sometimes negative perception of science and engineering careers; the damaging social constraints and stereotypes that affect students, especially girls; and in particular the rigor of the material necessary to understand subjects leading to science and engineering degrees—these factors must pale in comparison to the desire to understand and learn. In addition, in order to ensure that we educate students to be in the best position to innovate in the future, this desire must turn into a lifelong commitment. To reach the dual goal of both producing more engineers and better preparing them to participate in innovation, we must work to both enhance the attractiveness of these subjects or work to decrease those factors that cause the hesitation.

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[49] (*Electronic Engineering Times.* April 10, 2006)

Teaching and curriculum

Teaching is not a lost art, but the regard for it is a lost tradition.—Jacques Barzun

At the House of Representatives Education and the Workforce hearing on Subcommittee on 21st Century Competitiveness, Dr. Thomas Magnanti, Dean of the School of Engineering at MIT, described the values of engineering as rigor; implacable curiosity; disciplined creativity; an appetite for good, old-fashioned hard work; and a passionate, enthusiastic, can-do, hands-on, fix-it-now attitude.[50] Where better to instill these values in our population than in K-12 education? Public education is never to be an instrument to force opinions, but certainly these values are in line with what we profess to teach in K-12 education. According to Dr. Geoffrey Orsak, we manage to achieve some level of balance in the subject matter that we teach, but we have not achieved the excitement and rigor that other countries have managed to include in their educational systems.[51] The first step in tipping the motivation scales in favor of choosing science and engineering is to ignite our children's natural curiosity, to stimulate their desire to learn, and to improve access to material that can continue to motivate students. It is simple to see that teachers and curriculum are most responsible for introducing these aspects into the classroom.

The key concern is that teachers are prepared with the expertise, or even competency in the subjects of science and mathematics that enables them to adequately mentor and prepare those students who show increased interest and passion. By all accounts they are not. Eighty percent of high school mathematics teachers in 2002 were fully certified in mathematics, a number that steadily dropped over the previous 5 years.[52] That means that a fifth of math teachers in those grades either had no certification or was certified in a subject other than mathematics. Only 71 percent of teachers of 7th to 12th grade mathematics had at least a college minor in mathematics.[53] Especially troubling is the number of certified teachers teaching students in the problem years of 7th and eighth grades, with 60 percent and 58 percent respectively.[54] For schools in areas that have large low-income populations, the number of students taking math from teachers with full certification drops to 30 percent.[55]

Current policy efforts are focused in attempts to increase the number of science and engineering majors who choose teaching as a career by increasing available funding. This is a noble effort and deserves credit. Financial incentives are a strong motivator for people to choose a profession, and current efforts that call for funding to create joint training programs in science and education and for funding for students through their training hopefully will induce the kind of participation the policy intends. The authors of the reports and legislation that support these views hope that by increasing the level of expertise amongst our teachers, we can translate that into better resources for our students.

What needs to be further considered are the true incentives that attract teachers to teaching, in tandem with the motivation to study science, math, and engineering in the first place. Graduates who choose the teaching professions do not have the same level of academic performance as those who chose other professions.[56] The truly curious and driven students who choose to engage

[50] Dr. Thomas Magnanti, Testimony before the House committee on Education and the Workforce
[51] (*Electronic Engineering Times.* April 10, 2006)
[52] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: Nationl Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A). Figure 1-35.
[53] Ibid. Figure 1-34
[54] Ibid.
[55] Ibid.
[56] Ibid. Figure 1-6

in science and engineering curriculum mostly do so not with the goal of teaching in K-12, but rather to be engaged in technology and research. A move toward teaching, in many instances, means moving away from the very motivators that lead them to study science and engineering in the first place. Thus to choose to teach science and math in a K-12 education requires a dedication to two principles, initially to math and science, and then to teaching. The issue of increasing our supply of confident teachers is perhaps to adjust the incentives so that an aspiring scientist or engineer may engage in educating without sacrificing the dreams that lead her to conquer the hesitation to study STEM subjects. Math and Science teachers left the teaching profession at a rate of around 9 percent a year in 2001, with the majority either retiring or finding a career outside of K-12 education.[57] Those who left and found new jobs reported overwhelming improvement in many aspects of their careers.

Dr. William Wulf, president of the National Academies of Engineering, was asked what improvements in K-12 education would be most exciting. He expressed his desire for two improvements, adding the disclaimer that they were impossibilities. With over 16,000 school districts with different curricula, there is a need for national standards that would better promote science and mathematics instruction as well as curriculum across other subjects. The second improvement would be if teaching were once again a respected position, with compensation that reflected its importance in society. If it were so, we may draw more qualified teachers to the profession. He said that the most common academic background for middle school math teachers was physical education.

Public school teacher leavers who rated various reasons as very or extremely important in their decision to leave profession: 2000–01
(Percent)

Reason for leaving	Mathematics/ science teachers	Other teachers
Pursue another career	25.8*	19.7
Better salary or benefits	22.5	18.4
Retirement	21.8*	30.4
Changed my residence	20.4*	9.3
Health	17.8	9.3
Take courses to improve career opportunities outside education	12.1	9.1
Take sabbatical or other break from teaching	11.3	11.3
Feel unprepared to implement or disagree with new reform measures	9.2	8.4
Pregnancy or child rearing	9.1*	17.7
Dissatisfied with job description or responsibilities	7.1*	14.1
School received little support from community	5.9	6.5
Dissatisfied with changes in job description or responsibilities	4.8*	12.0
Take courses to improve career opportunities within education	4.5	7.6
Laid off or involuntarily transferred	3.7	3.1
Lack of certification	1.7	2.1

*p = .05, statistically significant difference between mathematics/science teachers and other teachers.

SOURCES: U.S. Department of Education, National Center for Education Statistics, 1999–2000 School and Staffing Survey; and 2000–01Teacher Follow-up Survey.

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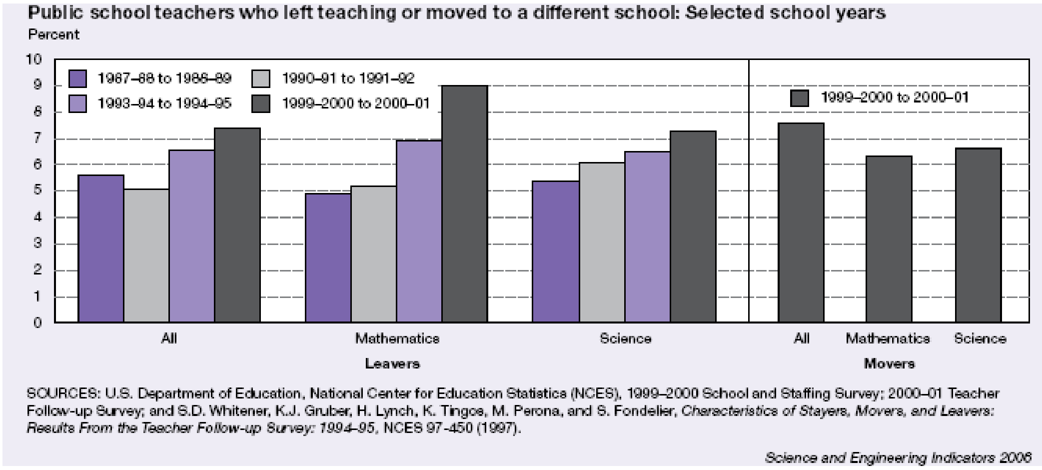
[57] National Science Board. 2006. Science and Engineering Indicators 2006. Two volumes. Arlington, VA: Nationl Science Foundation (volume 1, NSB 06-01; volume 2, NSB 06-01A). Figure 1-39



Policy Alternatives

If knowledge can create problems, it is not through ignorance that we can solve them.
Isaac Asimov

To address the issue of declining interest in and preparedness for science and engineering jobs among America's youth, we must be willing to make bold investments, both in monetary support and effort, to change the way we teach, and to attract more qualified people to teaching. Calls for policy shifts in education have come from all corners of the policy arena, including academia, business leaders, educators, and congress, and the current situation has prompted the President of the United States to issue an initiative that addresses America's ability to compete in the coming decades.

American Competitiveness Initiative:

The President unveiled his American Competitive Initiative (ACI) during his 2006 State of the Union speech. In the initiative, spurred on and informed by the National Academies report, he stated the objectives that will help the US remain competitive in years to come. The initiative "commits $5.9 billion to increase R&D investment, strengthen education, and encourage entrepreneurship," emphasizing his intent to continue investments that encourage innovation in the physical sciences and engineering. To improve educational efforts, the initiative proposes to augment the No Child Left Behind Act (NCLBA) with funds to increase professional development for teachers, attract new teachers to the classroom, provide access to flexible resources for worker training, and to develop research-based curricula, or teaching methods based on the results of experiments implementing successful curricula. Specifically, the ACI strengthens K-12 math and science education by enhancing our understanding of how students learn and applying that knowledge to train highly qualified teachers, develop effective curricular materials and improve student learning.

To address the issue of K-12 education, the President calls for the following measures.

Expanded Advanced Placement and International Baccalaureate Programs

The ACI plans to produce results by expanding the AP-IB Program to low-income students with the help of 70,000 new teachers. Teachers would receive incentives to undergo training to become qualified to teach AP/IB courses in mathematics, science, and "critical" foreign languages. The goal of the measure is to ensure that 700,000 students pass the AP/IB tests.

National Mathematics Advisory Panel

The ACI also calls for a national Math Panel to guide the creation of "research-based curricula" and proven methods for math education, with rigorous independent evaluation to discern their success. From this panel, the President intends to create programs for *Math Now* elementary and middles school math programs. Furthermore, NCLB accountability standards will include science assessments. For a discussion of the National Mathematics Advisory Panel, see Appendix B.

Federal Education Programs

The ACI calls for efforts to evaluate all STEM education programs run federal agencies to determine their effectiveness. This has happened in the form of the creation of the American Competitiveness Council, headed by the Sec. of Ed and including every federal agency that has education programs. To quote Rep. Boehlert (R-NJ): "The idea was prompted by a GAO report that found that there were hundreds of overlapping science and math education programs in the federal government."[58] The ACC report is due in the wintertime. "We need a diverse set of programs from different agencies, often programs working on the same problems- as long as that duplication is intentional and coordinated and the programs are being properly evaluated."[59]

Adjunct Teacher Corps

Finally, the ACI recommends the formation of an Adjunct Teacher Corps to encourage up to 30,000 math and science professionals to become adjunct high school teachers by 2015. To recruit these professionals, federal matching funds up to $25 million will go through the Dept of Education to "support partnerships between school districts and public and private organizations that encourage and prepare professionals to teach specific high school courses." A current example of such a program is described in Appendix A.

In the same state of the Union, the President reiterated his view that even though the American economy is strong and is growing stronger, the ACI calls on the partnership of industry, academe, and government, including local, regional and federal governments, to improve education. The ACI pledges $380 million to "build on the President's commitment to strengthen our Nation's education system," through engaging every child in rigorous courses that teach technical and problem-solving skills.

PACE Education Act

Teachers are the true soldiers of democracy. Others can defend it, but only teachers can create it -Gen. Omar Bradley

The Protecting America's Competitive Edge (PACE) through Education and Research Act, is currently in the Subcommittee on Education and Early Childhood Development, in the Senate Committee on Health, Education, Labor and Pensions. The PACE Act would legislate measures recommended by the National Academies (RAGS) report. The National Academies proposed several measures which have made impact on the policy world. The bill attempts to address the signs and symptoms of our nation's competitiveness as a whole, but the first recommendation

[58] GAO report that is sitting on my desk in the office
[59] Email correspondence

addresses the potential lack of talent, what the president of Rensselaer Polytechnic Institute, Shirley Jackson, terms the "Quiet Crisis."

10,000 Teachers, 10 Million Minds

The first recommendation of the National Academies report is to recruit 10,000 science and mathematics teachers annually by providing funding for university students in programs that combine technical majors with teacher training programs.

> "Our public education system must attract at least 10,000 of our best college graduates to the teaching profession each year. A competitive federal scholarship program will allow bright, motivated students to earn bachelors' degrees in science, engineering, and mathematics with concurrent certification as K–12 mathematics and science teachers."

The measures for this program would:

- Provide up to $20,000 per year for eligible applicants enrolled in combined programs leading to a technical Bachelors degree and teaching certificate.
- Carry a 5 year commitment to teach.

The PACE act authorizes support for such a program to be administered by the National Science Foundation through scholarships with funding reaching a steady $170 million by 2010. The legislation also sets the terms of the awards, and includes stipulations on where the 5-year commitment to teach may be spent, that new teachers may best impact schools most in need. Another section of the PACE Act would authorize funding for annual NSF fellowships in the amount of $10,000 for 5 years to qualified teachers who were awarded the NSF scholarship or had pursued a Masters degree in Mathematics and Science education. Funding for the fellowships would reach $45 million by 2011.

In addition, RAGS also calls upon the federal government to provide funding for the creation of more programs capable of training students in both pedagogical and technical skills. To that end, matching grants would establish integrated 4-year programs at qualifying universities that lead to bachelors and teaching certificates. In addition funding would create programs leading to a Masters in science and mathematics instruction. These partnerships with education schools would help to develop programs with in-depth technical content education and subject specific pedagogy, research experiences and training in education technologies. While the most consistent and powerful indicator of teacher performance is the proficiency of the teacher in their subject, joint programs would also help to build "cognitive roadmaps" or systems of evaluation and curriculum that maximizes a teacher's expertise. The National Academies point to the programs UTeach, at the University of Texas, and California Teach, at the University of California, as potential models for future grant receiving programs.

The PACE Act, if passed, will codify these recommendations and authorize steady funding increases to reach $500 million by 2013 for the establishment of programs leading to a bachelors, and $500 million by 2008 for master's program construction.

Strengthening the Skills of 250,000 Current Teachers

Secondly, the National Academies report recommends funding more opportunities for professional development for teachers of STEM education. The programs for further teacher development and training are diverse and it is hard to tell which are relevant, helpful, improve content knowledge and pedagogical skills.

> **"**Excellent professional development models exist to strengthen the skills of the 250,000 current mathematics and science teachers, but they reach too few in the profession. The four-part program recommended by the committee consists of (1) summer institutes, (2) master's degree programs in science and mathematics, (3) training for advanced placement and International Baccalaureate teachers, and (4) development of a voluntary national K–12 science and mathematics curriculum."

As noted above, the PACE Act calls for the development of masters programs as well as funding for teachers completing such programs. It also directs holders of math and science education masters degree to be intimately involved in the training of future teachers. It also creates AP-IB programs that align with the President's direction to train 70,000 additional AP-IB teachers and 80,000 pre-AP, IB teachers of science and mathematics. The goal of increasing the number of teachers of such classes would be to triple the number of students who take math and science AP, IB exams. To accomplish this goal, the PACE Act calls for grants to work with local educational agencies, establish AP, IB coordinators and directs Master Teachers—effective teachers with an advanced degree or certification—to hold summer institutes to train more teachers in teaching AP classes, and then to financially reward successful teachers and students who pass the math and science AP tests. In addition, the PACE Act would create a national clearinghouse for proven K-12 educational materials.

Involving the Workforce

You tell me, I forget; you teach me, I remember; you involve me, I learn.—Ben Franklin

As pointed out, our system of higher education, especially our doctorate programs, is the envy of the international community, and it is a resource that other nations, developed and developing, are eager to take advantage of, imitating our universities or sending students to the United States and luring them back with job opportunities. The strength of this extremely effective system is the apprenticeship of promising new researchers with the leading experts in the field, those who can promote collaboration with industry and government. The next generation is trained by those who, in essence, have their finger on the pulse of innovation.

At this time, our technical workforce is the possessor of five decades of knowledge, and in many cases, the sole possessors of specific technical details and their development. The impending wave of retirement as the baby boomer generation leaves their careers for "the pasture" poses huge problems of it own, not least of which are the impending burden on social security and Medicare, as well as a shorter knowledge half-life. However, relevant to the problem in K-12 STEM education, the workforce, and the science and math workforce in particular, represents the end game, the desired product. The current science and engineering workforce is comprised of individuals dedicated to the principles of Dr. Magnanti, Dean of the School of Engineering at MIT. While the work they do often lies outside of the limelight, they know intimately what it takes to be successful in the realm of technical work. To remain competitive, America must be able to not only sustain the quality of this product, but to redesign and to improve the product in anticipation for the future. Now is the time to involve our resource of technical professionals in the training of our students.

There are many extremely effective programs that bring students together with professional engineers and scientists and give them a chance to showcase their own creativity. The private sector, government agencies, and academia have always shown their generosity and concern in their sponsorship of science fairs, Olympiads, and summer science camps or classes. Take, as examples, the American inventor Dean Kamen's enthusiastic and enormously popular FIRST program for high school students[60], Intel's continued support for the Science Talent Search competition, the myriad programs that schools like Stanford and Harvard offer for motivated students, and corporate sponsorship for science fairs all over the country. It is no surprise that given the opportunity for interaction and challenge, students respond with such enthusiasm. The success of such programs is testament also to the passion and abilities of mentors involved. In many cases, the mentors are parents who themselves are engineers and scientists, or they are members of technical professions who augment their careers with opportunities to reach out to the communities.

One may take this participation as a clear sign that there are members of technical professions who have first dedicated themselves to their careers—for the love of the technical challenges, the better pay, the faster pace, the better career opportunities and certainly the better societal appreciation—but who take a vested interest in educating the next generation. As another example, the National Research Council demonstrated "that the potential interest in careers in secondary school science and mathematics education is much higher than the 0.8 percent of Ph.D.s who currently work in K-12 education.[61] Their perspective offers expertise, excitement, and exposes students to career possibilities, which are and will only be increasingly attractive for those with technical skills. Close cooperation between seasoned professionals and students would also perhaps provide a way to erase the negative image of the science nerd and give rationale to the hard work and dedication it requires to pursue technical majors. As a nation, we should consider more effectively tapping these skilled and concerned professional for the education of the next generation of engineers.

Part of the President's directives in the American Competitiveness Initiative is to produce an Adjunct Teacher Corps of 30,000. Currently, there seems to be no further discussions into how this should be accomplished, but there are certainly possible creative structures that would allow such a policy to augment the ranks of current teaching staff.

According to a 2004 report from the Department of Education, there are many alternative ways to receive a teaching credential. Forty-three states have programs that certify teachers in ways other than the traditional years of schooling that lead to certification. Consider the mid-career science and technology professional with a family and a mortgage. The attraction and desire to teach in public schools must necessarily be extremely strong to inspire such a professional to leave his job, go back to years of school—anecdotally, some people who study physical science and mathematics consider the teacher training curriculum unexciting—followed by an unpaid year of teacher training, to change careers. Such a process is inhibitive and such recruitment is rare.[62] For this professional, an alternative route would entail a short period, about six weeks, of summer training, followed by direct transfer into the classroom, allowing the teacher to immediately begin drawing salary and benefits as a teacher.

Couple this rationale on the part of the professional with the driving rationale for alternative teaching programs:

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61 National Research Council. 2000. Attracting Science and Mathematics PhDs to Secondary Education. Available at http://www.nap.edu/catalog/9955.html.

62 U.S. Department of Education, Office of Innovation and Improvement, Innovations in Education: Alternative Routes to Teacher Certification, Washington, DC, 2004.

> "[There are] many excellent teacher candidates [who] have made other career choices but would be open to becoming teachers if presented with the right offer… The challenge is to identify the types of potential candidates who would best meet district need and make them an offer they can't refuse."[63]

Thus, the aim of such programs is to cast a wide net and train and certify only those with the highest capabilities and greatest motivation; that is, to "recruit widely, select carefully." [64]

While alternative certification programs differ in method and requirements, the Department of Education notes a congealing consensus on critical program characteristics:

a) The program has been specifically designed to recruit, prepare, and license talented individuals who already have at least a bachelor's degree.
b) Candidates pass a rigorous screening process
c) The program is field-based
d) The program includes course work or equivalent experiences while teaching.
e) Candidates work closely with mentor teachers.
f) Candidates must meet high performance standards for completion of the program.

Many such programs have arisen to meet the shortage of teachers and to offer a more attractive, less prohibitive way into the teaching profession. The number of teachers teaching on emergency credentials—especially in schools with high concentrations of low-performing students—has risen with the percentage of novice teachers who leave the profession, indicating there recruitment is an attempt to add personnel. But while teachers on emergency credentials may have the potential to be good teachers, they have too often been left to fend for themselves in the very districts and schools where students are most in need of effective teaching.[65] Alternative teaching programs attempt to remedy this problem by offering an option to aspiring teachers that does not entail years of schooling, in an effort to attract a more diverse array of potential teachers, and also to provide these teachers with much better training and support than the typical teacher on an emergency credential.

To accomplish the President's mission of creating an Adjunct Teacher Corps, the federal government should perhaps look to these programs to provide a means to meeting the teacher shortage problem. The 2004 ED report supplies a caveat that their case studies and collection of data on these programs does not represent a scientifically conducted survey that allows conclusions on "what works", but stresses that programs must fit local circumstances. If the federal government were to direct attention to programs like these, to commission more research to tease out "what works" for specific systems, to fund the creation of more such programs, and to perhaps offer additional financial support to professionals choosing to attend such programs, it would offer an alternative way to increase the number of certified and capable professionals.

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[63] U.S. Department of Education, Office of Innovation and Improvement, *Innovations in Education: Alternative Routes to Teacher Certification*, Washington, DC, 2004.

[64] Ibid.
[65] U.S. Department of Education, Office of Innovation and Improvement, *Innovations in Education: Alternative Routes to Teacher Certification*, Washington, DC, 2004.

To further follow the rationale of presenting these professionals with an offer they cannot refuse, it would be wise to consider further ways to "sweeten the deal." We would like to entice professional scientists and engineers who work in industry, government, and academia, those with practical experience who apply their studies and knowledge of their fields to their work everyday. With the practical knowledge of the engineering and science work world, these people would be valuable teachers if we consider the high school classroom also as an apprenticeship setting. To lure them to teaching positions, we could consider two types of systems, one in which a science or engineering professional is allowed to teach a class part time, and one in which the professional may take a sabbatical to teach.

The first situation, in which a professional enters a school to teach part time, is one that happens all the time. Take, for example, all of the high school coaches, athletic and otherwise, who work in other jobs and coach after school. Many students point to these dedicated educators who give their time, many times with a pay cut, as some of the most influential educators of their lives. Thus, from the educational institution's standpoint, there is no logical barrier to such professionals entering classrooms in similar capacities, and held to the same standards as all other teachers. It would be in our best interest to entice like minded technical professionals to pursue teaching certificates through alternative means and to offer their expertise and perspective in a part time capacity.

In the second situation, a mid career professional in science and engineering might take a sabbatical to teach a class. This option may pose more problems for the institution, since in this case, if there is a need for such a teacher, the position would have to be filled again the following year. However, if this technical professional is a certified teacher, for a given year she could teach a standardized supplementary curriculum, for example, a third grade science curriculum or a high school anatomy course. On the other hand, the programs like New York Teaching Fellows mentioned in the 2004 Department of Education report often expect attrition rates.[66] A scientist or engineer on a one year sabbatical from their careers and a year of teaching would be equitable to the attempts made by alternative teaching credential programs to fill short term needs.

In both situations, it would be possible to involve career professionals more closely in the lives of students. Programs like these would widen the horizons of the education system.

- For students who showed interest, career scientists and engineers would have a better grasp of the available opportunities, including summer internships with high tech firms, summer programs at local universities, and be able to offer consistent and challenging advice on career paths.

- Those in technical professions recognize the necessary qualities in the workplace, including teamwork, communication, problem-solving, competitiveness, and accountability, all features that the No Child Left Behind Act aims at improving (NCLB). Such professionals would bring all of these features to the classroom, and set an example for the students.

- Technical professionals in the classroom would have the potential to change the image of engineering and science, bringing it from the back-office to those most in need of exposure to science and technology. Even further, actions like these would show students that as engineers and scientists they can have an impact on the next generation and that such careers do not mean isolation.

[66] Ibid

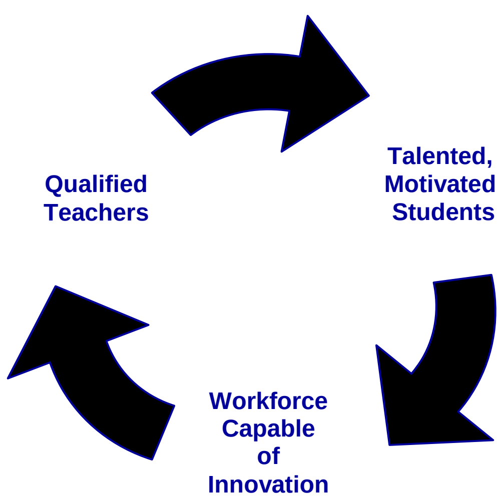
- Enabling older professionals to also teach would invigorate the workforce. If one considers the number of doctorate holders with an ability to teach but without the opportunity to pursue a faculty position, one could envision the number of people for whom such an opportunity would be a boon. It could offer those involved a change of pace, a change of scenery, and the rewards of being able to reach out to the community, which may also enhance the rewards of industry jobs.

- Just as enhanced technical education will enrich the lives of today's youth and make them valuable citizens, if career professionals are allowed to experience for themselves the public education system, we would increase the number of people intimate with its positive aspects as well as the challenges it faces, empowering those in a position to call for change.

- Accomplishes the President's goal to create an Adjunct Teacher Corps.

- Advanced Placement and International Baccalaureate programs would be particularly attractive places for career professionals, where their expertise would allow them the chance to further challenge students. This would help to accomplish the President's goal to promote challenging coursework.

- By setting an example to other community members, professional/teachers could also increase the prestige of the teaching profession, and supplant the colloquialism that "those who can, do; those who can't, teach," with, "Those who can, do, and teach my kids."



Involving the Workforce Completes the Cycle

Recommendations

The future of our country's competitiveness depends on improvement in the K-12 education, and our ability to better train a creative workforce for the future. To do so, the science and mathematics competency of our teachers and their ability to motivate and prepare their students is a crucial piece of the puzzle. We must recruit the best and the brightest to the teaching profession. In addition, we should fundamentally change the education system by promoting more involvement by part-time teachers/science and engineering professionals. By eliminating the time commitment for full certification and by providing financial incentives, we can allow professional scientists and engineers to fulfill both their desire to teach and to participate in the innovation and technology that originally drew them to their careers. In such a way, we may hope to augment the technical expertise of our educational workforce and achieve our goals of improving K-12 education.

1. Congress should pass and fund the initiatives of the PACE legislation directives for K-12 education.

The Protecting America's Competitive Edge in Education and Research Act is designed to attract the finest minds to the teaching profession of the next generation of the finest minds, and invests in improving the technical capabilities of our current K-12 math and science teachers.

It increases the financial incentives for America's talented students to commit to education, thereby improving the most powerful indicator of student success, the level of teaching. We can hope to thereby increase the number of students with instructors who have Bachelor's level knowledge in a technical field while also promoting the spread of research-based, subject specific teaching tools.

Master's level programs in Mathematics and Science education would offer yet another way to augment our current teaching resources by serving as experts who could help to locally train and assist our teachers; hopefully they would prove to be powerful for the professional development of future educators.

In addition, if the nation's public education system were to triple the number of students both taking and passing the AP and IB exams, trends indicate we would see a significant jump both in the number of students graduating from college, and in the number of students prepared to pursue engineering and science majors.

This bill, as written, has 62 cosponsors in the US Senate, indicating the amount of support it currently receives, and support should continue.

2. Develop standards for programs that provide alternative means to teacher accreditation. Fund the creation of pilot federal programs to demonstrate effectiveness.

Our current workforce is the pride of this nation's economy, and we should do more to encourage those who have helped to make our nation technologically competitive, to help make our education system stronger than ever.

The federal government should lower barriers to professionals wanted to teach by promoting programs that accredit teachers by other means than traditional certification programs.

First, Congress must commission research on effective ways to produce competent teachers with dedicated mentors and support.

Leaving the selection of qualified candidates to the program directors, the federal government should pay program fees for career scientists and engineers seeking to complete alternative credential programs, reducing the financial burdens such professionals would incur.

3. Support the workforce of science and engineering professionals in education the next generation of by creating partnerships between education institutions and the private sector and national laboratories

Using the idea behind apprenticeship programs, we can see the rationale for recruiting career professionals to partake in classroom instruction in technical subjects.

The federal government should support such programs by working with state and local governments to create partnerships between education institutions and the private sector and national laboratories.

First, congress should mandate that employment opportunities be made available for qualified science and engineering professionals with a teaching degree.

Secondly, Congress should provide financial incentives—tax credits or funding to corporations that support employees in pursuing training to become teachers and who teach in either a sabbatical format or in a part-time capacity. Similar sanctioning within the national laboratory infrastructure would offer access to additional skilled resources.

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All the inspiring teachers in his life

Author Bio

Anthony Azevedo graduated in 2005 from the University of California Berkeley in Engineering Physics. After a turbulent DC summer, he will start school at University of Washington in Seattle to pursue a PhD in Physiology and Biophysics.

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Appendix A: ReSET—Inspiration is Innovation

Retired Scientists, Engineers, and Technicians (ReSET) is a private organization in the District of Columbia dedicated to bringing science and engineering to the classroom. The organization started by Dr. Harold Sharlin recruits volunteers from all disciplines who for 1 hour a week for 6 weeks, enter 4^{th} grade classrooms across the district to demonstrate science and technology through experiments. The experiments are designed to engage the minds of the children and to prepare them for a field trip to a destination where they can observe science and technology at work. The program has run for 22 years, and continues to grow and be very successful, stimulating not only the classrooms of children with the opportunity to get involved, but the volunteers. ReSET provides the chance to pass on the passion and excitement for technology and innovation that is a precious commodity in today's educational system, and offers the opportunity to help develop the next generation of innovators.

In today's world, many experts suggest that we must better educate a work force that will guarantee the future competitiveness of America in the realm of technical innovation. That starts in the K-12 education, where we can isolate a failure in the system to the years between 4^{th} and 9^{th} grades. Math and science proficiency drops dramatically in those years when compared to test scores of students in other countries. One of the measures addressed in the President's American Competitiveness Initiative suggests tapping one of our least used resources in education: our population of experienced engineers and scientists.

For many people in technical careers, their pursuit was influenced by a parent, a mentor, someone with experience in a technical discipline who was able to inspire them and show them what a scientist or engineer did for a living. There is also invariably a drive, a hard-working attitude that gets passed on. If one thinks about all the students who would benefit from meeting just such a professional, it is easy to see the logic in recruiting them to donate their time and experience to youngsters. A great example of a program that helps put experienced professionals in the classroom is ReSET, Retired Scientists, Engineers and Technicians, and its founder and CEO, Dr. Harold Sharlin

Dr. Harold Sharlin met me at the University of DC campus, and was kind enough to give me an introduction to his program. With a BS in EE and a PhD in History, he taught at History of Science at Iowa St. University until 1976. With a grasp of the past and obvious gratitude for his own education and rewarding career, it is no surprise that when he moved to DC to work for Iona Senior Services, he recognized the tremendous potential of retired professionals. So many of them wanted to give back, and were looking for ways to contribute their experience, that he conceived of starting a collaboration with DC schools in which senior citizens could participate in classroom activities. In a classroom, they could provide a spark that could turn students on to math and science at a time crucial to a child's education, when they would see they could like technology and that there was no reason they could not understand it.

It was tough to break in to the schools until he figured out who could make that kind of thing happen, the principals. He originally tried talking with middle school teachers but realized they had a set curriculum which took all of their time and were reluctant to make room in their teaching schedule to include the ReSET program volunteers. He found an elementary school principal to introduce the program into her school, and set up meetings to begin dialogue between his original 7 volunteers and teachers. He says, "It was a goldmine."

The program is now 35 volunteers in the DC area, and teachers fight to get into the program. The crucial task of communication is handled by a paid volunteer coordinator who ensures that the volunteers, professional engineers or scientists often used to the responsiveness of the business world, are able to speak to teachers who frequently do not have time to return calls immediately. The volunteers give a presentation in 4^{th} or 5^{th} grade classes for 1hr a week for 6 weeks, giving the kids continuity, an opportunity to ask burning questions that they thought of over the week, and a real chance to get to know a retired scientist or engineer. In the hour they present an experiment, and though the program offers reimbursement for the projects, the volunteers often pay out of pocket. Dr. Sharlin says, "The kids have an attention span of 30 sec., do something! If you lecture, you're dead." If the girls hang back, they make special effort to involve them. With his background in EE, he likes to show the kids the principles of electro-magnetism and does Faraday's experiment in which a moving magnet creates a current through a wire. He sets up the experiment on the table at the front of the room and has the kids come up, take the magnet, and try to get the needle on the voltmeter to move. They play around a little, then he gives the string attached to the magnet a sharp tug. "Oh, oh, oh, the needle jumped!" Other demonstrations include bones and rubber bands for muscles (the gorier, the better), some basic calculus demonstrations, and levers and mechanics. There are guidelines for the teachers while this is going on: be responsible for discipline, be present in the classroom, participate in the science activity, provide guidance for appropriateness of material, and coordinate field trips. The field trip is typically to someplace where the students can apply what they learned throughout the experiments. Dr Sharlin took his students to a generating plant and when asked what was needed, together with magnetism and conductors, to generate electricity, a student raised his hand, saying, "Motion."

"I could have kissed the kid," Dr. Sharlin said.

At the ReSET's inception, Dr. Sharlin had accounted for the fact that the children would warm to the activity and respond with enthusiasm and engagement. A child's mind will soak up such an experience. What he did not account for, however, were the volunteers: how responsive they are, how willing to give their time, how well they fit into the classroom, how much fun they have. There are those who want to teach in Anacostia, in some very poor, underperforming urban schools, where they feel the children need them the most. There are those who would prefer not to teach there, thinking the children are too far behind to spend time on experiments. It is hard to recruit new volunteers; he says, "Grown men shake at the prospect of teaching. But I get them in front of the door, push them in, and give them a minute to discover how rewarding the experience will be."

It is eye-opening to talk with Dr. Sharlin, to hear his views on education and the interaction between generations. With a great grandchild entering 4^{th} grade, he notes that it's now a three-generation gap they are bridging. What is most striking is that if we are to engage in this kind of program, it's going to be the efforts of people like Dr. Sharlin and his generous volunteers, those with the commitment and energy to get involved and to see the rewards. As Dr. Sharlin said, these people are the movers and the shakers, "Where the rubber hits the road," and they have so much to give.

Appendix B: National Mathematics Advisory Panel

On April 18, 2006, the President created the National Mathematics Advisory Panel and charged the 17 expert panelists with the mission to strengthen math education through research. An interim report from the panel will be issued by January 31, 2007, with a final report to follow by February 28, 2008. At the inaugural meeting on May 22, the Mathematics Advisory Panel was charged with making recommendation based on the best scientific evidence on the following:

a) the critical skills and skill progressions for students to acquire competence in algebra and readiness for higher levels of mathematics,
b) the role and appropriate design of standards of assessment in promoting mathematical competence,
c) the processes by which students of various abilities and backgrounds learn mathematics,
d) institutional practices, programs and materials that are effective for improving mathematics learning,
e) the training, selection, placement and professional development of teachers of mathematics in order to enhance students learning mathematics,
f) the role and appropriate design of systems for delivering instruction in mathematics that combine the different elements of learning processes, curricula, instruction, teacher training and support and standards, assessments and accountability,
g) needs for research in support of mathematics education,
h) ideas for strengthening capabilities to teach children and youth basic mathematics, geometry, algebra, calculus and other mathematical disciplines,
i) such other matters relating to mathematics education as the panel deems appropriate.

The content of the panel's report has the potential to offer significant direction for how mathematics should taught in this country. Some on the panel suggested that with a such a summary of recent research, we may be able to move standards away from high-stakes multiple choice testing towards other measures of performance that more accurately assess students skills while addressing problems like lost class time and potential cheating on the part of teachers.