Raising Engineers

A LOOK AT THE FEDERAL GOVERNMENT'S ROLE IN INCREASING K-12 STUDENT INTEREST IN, AND PREPARATION FOR, UNIVERSITY PROGRAMS OF ENGINEERING

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ABOUT THE AUTHOR

Hilary Pence Steinway is a rising 5th year Mechanical Engineering and Mathematics student at Southern Methodist University in Dallas, Texas. She recently completed her third Co-Op Internship term with Hensel Phelps Construction Company, on the DFW Airport People Mover Project. At SMU, Hilary has served as President, Secretary and Student Advisor to the SMU section of the Society of Women Engineers. She also has served as the mechanical engineering representative to the Student Engineering Joint Council, which meets with the Dean of the School of Engineering to address student concerns. Hilary has been involved in the SMU Gender Parity Initiative to reach parity within the SMU School of Engineering by 2005. She has volunteered with numerous K-12 outreach programs regarding engineering and technology.

ABOUT WISE

WISE, Washington Internships for Students of Engineering, is a 10 week program designed to introduce students of engineering to the world of public policy. Each year 12-16 students are selected during a nationwide competition to participate in the program. During the internship, the students learn how government officials make decisions on complex technological issues and how engineers contribute to the public policy process. Through the course of the ten weeks, students interact with leaders in the Congress and Administration, industry and prominent non-governmental organizations. The program concludes with presentations and published papers by each of the interns on a topical engineering related public policy issue.

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EXECUTIVE SUMMARY

During the 20th century, the world became increasingly dependent upon technological marvels, and it will continue to do so through the 21st century. Yet for as many contributions engineering and engineers have made to these advances, the engineering profession has received very little recognition for the design and development of the technologies and infrastructures that define America's national security, economic prosperity, and every day standard of living. The American workforce is not equipped to handle the technological expectations of today, nor are our elected representatives qualified to make decisions about technology-based policy issues. Additionally, the nation's K-12 education system is below average for developed nations in teaching science, technology, engineering, and mathematics, leading to a decline in population for future generations of engineers. Engineering graduate rates have even been flat, at around 64,000 graduates per year, for the past decade. There are two main issues to address in the search for a solution: Improving student performance in pre-engineering disciplines and increasing student interest in pursuing engineering when they reach the collegiate level.

In addressing these issues, several organizations, institutions, corporations and even state government agencies have initiated programs targeted at improving K-12 performance in the engineering related studies. Unfortunately, no true measurement standards are available, and thus proving success of any of these programs is difficult. Some grass-roots level victories have been experienced, seeing children turned on to the world of engineering. The important issue is that there needs to be more than just random grass-roots victories. These programs need to be expanded nationally, to ensure the United States remains a leader in this technologically ruled information age.

Problems arise in the attempts to grow these locally established, even successful programs, when the issue of funding is addressed. Fiscal responsibility usually falls to the state departments of education, and math, science and engineering/technology related improvements to any curriculum fall under different level of priorities from one state to the next. Even when money is allocated, it may be taken away within a year of trial due

to changes in governmental priorities. The federal government needs to take appropriate steps towards regulating spending of educational finances.

Finally, students need to be introduced early on and continuously to the world of engineering and technology. Through hands-on events and mandatory curriculums, children can be given the chance to explore the opportunities available through a career in engineering. They must have their curiosity directed toward engineering as early as pre-school, and grown and nurtured through high school graduation, so that young children are telling their parents "When I grow up, I want to be an engineer!" and are growing up to see that dream realized.

INTRODUCTION

In 1879, Thomas Edison brought the lightbulb to American homes. The Wright brothers made the first successful powered, piloted flight in 1903. In 1913, Henry Ford invented an improved assembly line, introducing the conveyor belt in his car factory. Fifty-six years later, the United States put man on the moon. Now, in 2003, we have the internet, CAT scans, satellite TV, space exploration….the list goes on. The world has become technologically revolutionized. From driving their cars to growing new foods, to answering their cell phones and preserving their environment, technology is making a significant impact on the daily lives of every single American citizen. And in today's high-tech market, over two-thirds of American economic growth stems from technological innovation.[1] Yet over the past ten years, the United States has experienced a troubling flat rate of students graduating with engineering degrees. Why is this happening and what does it mean for our country?

In today's technology-driven society, the US must produce a technologically minded workforce to ensure national prosperity. Texas Senator Kay Bailey Hutchison believes we need to recruit more engineering students, and feels that "to compete in the global economy, we must maintain our innovative edge".[2] Graduates of engineering bring highly prized skills into many aspects of the American workforce, influencing critical areas such as national security systems, medical advances for our aging population, and many other beneficial sectors. Improving engineering education can only lead to positive results benefiting economic, civic and intellectual activities. As our neighbors develop higher levels of technology, the United States must remain ahead to maintain our competitive advantage.

Why do many students show little or no interest in pursuing science and technology degrees during their college experience? According to the 2000 National Association of Colleges and Employees studies, engineering and computer science graduates take the top nine spots among the highest paid graduates with bachelor's

[1] Congressman Mike Honda's Internet Website. School Modernization and Technology. http://www.house.gov/honda/InCongress/education.html#schoolmodernization Accessed 8 July 2003.
[2] Hutchison, Kay Bailey. Kay Bailey Hutchison: We need to recruit more engineering students. Dallas Morning News Website. http://www.dallasnews.com/cgi-bin/bi/gold_print.cgi . Posted 1 March 2002

degrees in the nation.[3] It would be expected that pursuing careers in a field where advancement and high salaries are practically guaranteed would be highly desirable. Yet the numbers show otherwise. For varying reasons, students are not attracted to engineering degree programs. There have been countless attempts at improving the national opinion on the importance of engineers, yet few successful. In fact, most Americans don't know what an engineer is or what engineers do.[4] This may be due to several reasons, the most prominent of which is funding. Since K-12 education is regulated largely on a local and regional level, there is not much funding for programs designed to improve technological literacy. If there is going to be an improvement in our nation's position in the global community, the federal government must become involved, utilizing successful case studies and federal funding to do so.

Another key set back is the national image of the engineer. People think of those who study and work as engineers as non-social, dull, "nerds" who wear pocket protectors and sit in cubicles all day avoiding the outside world. What people aren't aware of is that graduates of engineering programs go on to earn law, medical and business degrees. In fact, out of Fortune's top 200 CEOs, engineering was the most common background, with 22% earning undergraduate engineering degrees.[5] For those who choose a career path within engineering, a lifetime of learning, exploring, and creating awaits. If students are presented with this sort of information and can see the many different options available through engineering, they will be more likely to make an informed decision that engineering is the right course of study for them.

For our next generation of college graduates to be competitive in the global world of technology, we need to take steps now to encourage more young students to pursue engineering. Through improved funding methods, better quality teachers, and more national-scaled outreach programs, this goal is possible.

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[3] Rice University Internet Website. Career Advising: National Salary Statistics. http://www.ruf.rice.edu/~che/advising/salary_starting.htm Accessed 29 July 2003.
[4] National Academy of Engineering. Raising Public Awareness of Engineering. The National Academies Press. Washington, D.C. 2002.
[5] iBid.

THE NEED FOR ENGINEERS AND TECHNOLOGICALLY MINDED CITIZENS

Past, Present, and Future: By the Numbers

Over the past ten years, the number of American students graduating with degrees in engineering has been flat. The peak for our nation was in 1986, when there were 78,178 engineering undergraduate degrees awarded in the United States.[6] That level dropped to a low of about 63,000 in 1990, and has since rebounded only slightly to approximately 65,000.[7] Although engineering is among the fastest growing professions in America with the number of available jobs growing daily, the number of high school seniors planning to study engineering has fallen from 9% in 1992 to 6% in 2002.[8] Even those students that make it into university programs of engineering face challenges too great for their secondary school preparation, which is a leading factor of the attrition rate of at least 40% in the nation's engineering schools.[9]

Beyond the undergraduate level, fewer students are pursuing graduate level engineering degrees, and with an expected exodus of nearly 2.2 million teachers by the year 2010, this is a concern as we are without the presence of replacements.[10] This should concern the public as fewer teachers means lower quality of education. Unlike other areas of study, math and science programs are facing drastic shortages of teachers, and university graduates in these areas are tempted away from teaching by better offers. Schools are facing fierce competition from the private sector in recruiting and retaining qualified math and science teachers.[11]

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[6] Engineering Workforce Commission of the American Association of Engineering Societies. 2000. Bachelor's Degrees Rising. Engineers 6(4):1-4.
[7] National Academy of Engineering. Raising Public Awareness of Engineering. The National Academies Press. Washington, D.C. 2002.
[8] iBid.
[9] American Society of Engineering Education. Engineering Education and the Science & Engineering Workforce. Public Policy Internet Website. http://www.asee.org/policy/wormley.cfm. Accessed 3 June 2003.
[10] The American Association of Engineering Societies; The Engineering Workforce Commission http://www.ewc-online.org/ Accessed 10 June 2003.
[11] Statement of Administration Policy (Bush Administration). House Approves Bills to Help States & Schools Put a Qualified Teacher in Every Classroom. News from the Committee on Education and the Workforce Website. http://edworkforce.house.gov/press/press108/07jul/teachersph070903.htm

International Competition

Student Achievement

As compared to other nations, we are producing engineers at a much slower rate. Every year Japan produces 2/3 more engineers than the United States, the EU produces twice as many, and China three times the number of American engineers.[12] This is especially disturbing when compared to the populations of these countries. For example, Japan only has about half the population of the United States, yet they are producing 2/3 more engineers every year.[13] Similarly, the European Union only has 1.5 times the population of the U.S., yet is doubling our efforts, and even though China is comparable in proportions to us, they are still graduating more engineers and creating more competition.[1415] In terms of the proportion of 24 year olds who hold natural science or engineering degrees, the United States has fallen from third to thirteenth in the world in the last 18 years.[16] Even more staggering is the fact that American children are far behind the mathematical and scientific skill levels of those of other countries. According to the Secretary of Education's Mathematics and Science Initiative, U.S. 8th graders are ahead of only Italy and New Zealand for mathematics and science performance among industrialized nations.[17] In fact, American 8th grade students are given the same material for testing purposes that 5th graders in Singapore are expected to know.[18] The lack of strong education programs in these disciplines in primary and secondary schools is likely to blame. Japan, for instance, has programs in place requiring all school children to study technology based courses as part of the primary and secondary curriculums.[19] This is creating a graduating class ready and willing to take on the challenges of today's high-

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[12] The American Association of Engineering Societies; The Engineering Workforce Commission. http://www.ewc-online.org/ Accessed 10 June 2003.
[13] Encarta Online. Japan People & Society. http://encarta.msn.com/ Accessed 1 August 2003.
[14] Eurostat Website. Eurostat Yearbook. www.europa.eu.int. Accessed 1 August 2003.
[15] China Population Information and Research Center. www.cpirc.org.cn/eindex.htm. Accessed 1 August 2003.
[16] From Congressman Sherwood Boehlert's Internet Website News Release. House Approves Boehlert Bill to Bolster Undergraduate Science and Math Education, Increase High-Tech Workforce. http://www.house.gov/boehlert/techtalentvote.htm Accessed 23 July 2003.
[17] U.S. Department of Education. Mathematics and Science Initiative Concept Paper 5/15/2003
[18] iBid.
[19] Murata, Shoji. Stern, Sam. Technology Education in Japan: An Overview of the Japanese Educational System. http://scholar.lib.vt.edu/ejournals/JTE/v5n1/murata.jte-v5n1.html. Accessed 14 July 2003.

tech work place. The students in Japan and other foreign countries where engineering and technology are stressed early in education are graduating from high school with the necessary knowledge, skills, and desire to enter into university programs of engineering.

National Security

According to the U.S. Commission on National Security in the Twenty-First Century, "more Americans will have to understand and work competently with science and math on a daily basis…the inadequacies of our systems of research and education pose a greater threat to U.S. national security over the next quarter century than any potential conventional war that we might imagine."[20] The contributions engineers make towards national security range from defense missile development to cyber-security. Since the events of 9-11, the importance of security has been even more stressed, placing more weight on engineers to continue to develop newer, better defense and emergency response systems. Congressman Ralph Hall of Texas stated that in the post 9/11 world, "We have come to a moment in history in which we must recognize the value of science, not only as a major contributor to our quality of life, but also as the key to our future national security. Without cutting edge research, we would not have been equipped to respond so rapidly and effectively to ... those heinous attacks in New York and Washington."[21] He is one of few representatives that have acknowledged the need for better math and science education in America's schools as a method for securing the nation's global leadership in research and technology.

Economic Prosperity

On an economic level, the United States is not producing enough engineers to meet the growing industry demand. In 2002 there were approximately 73,000[22] engineering and computer science bachelor's level degrees awarded to students in the

[20] Website for the U.S. Department of Education. The Facts About…Science Achievement. http://www.nclb.gov/start/facts/science.html Accessed 21 July 2003
[21] Hall, Ralph. Congressman Ralph Hall's Internet Website News Release. Hall Stresses Importance of Science in Public Policy Address at Rice University. http://www.house.gov/apps/list/press/tx04_hall/rice.html Accesses 24 July 24, 2003
[22] Hutchison, Kay Bailey. Kay Bailey Hutchison: We need to recruit more engineering students. Dallas Morning News Internet Website. http://www.dallasnews.com/cgi-bin/bi/gold_print.cgi. Accessed 16 June 2003..

United States. Yet American industry still had to search abroad to fulfill another 115,000 positions requiring engineering graduates.[23]

Some Americans feel there is not such a dramatic need to increase the number of US graduates in engineering. The opinion is that hiring employees from abroad is often less expensive.[24] Congressman Mike Honda, of California, would disagree. His representation of the 15th District of California, which includes Silicon Valley, has him highly involved in all areas related to technology.[25] The unemployment rate in the Silicon Valley area, or Santa Clara County, is currently among the highest in our nation, at about 8%,with too many technological employees for the number of jobs available. [26] Yet Congressman Honda will be the first to argue the importance of producing more American engineers. As he points out, the economy is slow, but when it rebounds the technology fields will skyrocket and his district will need large numbers of engineers quickly.[27] After the events of 9-11, student and work Visas are backed up, taking more than twelve months to successfully complete the process to apply for a Visa and hire employees from abroad, assuming they desire to work in the United States.[28] Today's trend is that student Visas are acquired to receive education at our Universities, where current technology is researched, developed and taught.[29] Upon graduation, however, the foreign students choose to take their American education and knowledge to their home countries, to help improve their own economies.[30] This is creating greater competition for the United States, largely at the expense of our tax payers.

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[23] Hutchison, Kay Bailey. Kay Bailey Hutchison: We need to recruit more engineering students. Dallas Morning News Internet Website. http://www.dallasnews.com/cgi-bin/bi/gold_print.cgi. Accessed 16 June 2003..

[24] Levin, Alan. Personal Communication. 8 July 2003. ???

[25] Werwa, Eric. Legislative Director, Office of Congressman Honda, California. Personal communication. 30 June 2003.

[26] Publication of the Minority Staff, Committee on Government Reform. Unemployment Analysis: Prepared for Reps. Anna Eshoo, Zoe Lofgren, Mike Honda. December 2002, January 2003.

[27] Werwa, Eric. Legislative Director, Office of Congressman Honda, California. Personal communication. 30 June 2003.

[28] Internet Website for the United States Embassy in Bogota, Columbia. How Long Does it Take to get a Visa? http://bogota.usembassy.gov/wwwsc045.shtml Accessed 29 July 2003.

[29] Werwa, Eric. Legislative Director, Office of Congressman Honda, California. Personal communication. 30 June 2003.

[30] American Society for Engineering Education Internet Website. Public Policy: Engineering Education and the Science & Engineering Workforce. http://www.asee.org/policy/wormley.cfm Accessed 21 November 2002.

According to the 2000 report, Before It's Too Late: A Report to the Nation from The National Commission on Mathematics and Science Teaching for the 21st Century, there will be an additional 20 million jobs by 2008, created by the technology-driven economy of the 21st century.[31] The study found that only 20 percent of the present workforce possess the required skills for the predicted 60 percent of new jobs in the early 21st century.[32]

Technologically Minded Policy Makers

As our nation and world evolve to a more technologically based lifestyle, the level of understanding of all things technology-based among citizens and government officials does not seem to be changing, and this should be a major concern. The policy makers and leaders of the United States must be educated to be prepared to create well-informed, practical, plausible laws. In 2002 there were only 8 House Representatives and 1 Senator holding engineering degrees.[33] Of those, only two were licensed Professional Engineers. There are very few members with science, engineering, or technology backgrounds serving on either the house or senate science committees, yet these committees make very important decisions regarding these subjects.[34] It is essential that K-12 education of science, technology, engineering and mathematics be improved to prepare today's students to become tomorrow's productive leaders.[35]

Focusing On The PreK-12 Level

There are different levels to primary and secondary education in America. These can be broken down to different stages, educationally. Younger children are not ready to handle complex equations, or abstract theories.[36] They should be introduced in a fun,

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[31] From Congressman Sherwood Boehlert's Internet Website News Release. House Approves Boehlert Bill to Bolster Undergraduate Science and Math Education, Increase High-Tech Workforce. http://www.house.gov/boehlert/techtalentvote.htm Accessed 23 July 2003.
[32] iBid.
[33] National Academy of Engineering. Raising Public Awareness of Engineering. The National Academies Press. Washington, D.C. 2002.
[34] Staff of the House and Senate Science Committees. Personal Communications. 25 June 2003.
[35] American Society of Mechanical Engineers. Improving K-12 Science, Technology, Engineering, And Mathematics Education: Options for State Legislatures. November 2002.
[36] Werwa, Eric. Legislative Director, Office of Congressman Honda, California. Personal communication. 30 June 2003.

exciting way to all that engineering does for them in their everyday lives. As the children grow, so do their capabilities for understanding more technical aspects.[37] By high school graduation, students should have enough math, science and technology/engineering experience to be comfortable deciding if engineering is the right course for them in college.

Grades PreK-5: An Impressionable Age

Ask any child what they want to be when they grow up. The expected responses abound…"fireman!", "doctor!", "dancer!", but rarely "engineer!" While children may be fickle and change their mind on a weekly basis, the fact remains that when they ponder their future, all of those possible occupations and more filter through their mind. These early thoughts and dreams for their future lead them to pursue the opportunities and learn about the subject, leading to an informed decision when they get to that point in their life. Without being introduced to engineering early in their lives, children can not be expected to graduate high school fully aware of their option of pursuing engineering as a career.[38] From pre-kindergarten until fifth grade, a strong foundation of math and science is important to set children up for success in these disciplines. This is a very impressionable age when role models can make a huge impact.[39] Through 5th grade, research shows that all students progress at fairly equal rates, and all students are prepared to enter middle school with decent preparation in math and science.[40] It can be concluded that the problem at this level is a lack of understanding of what engineers do that prohibit children from becoming interested in engineering. It is at this age that the seed of inspiration needs to be planted, so children will be aware of the possibility of "growing up to be engineers!"

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[37] Werwa, Eric. Legislative Director, Office of Congressman Honda, California. Personal communication. 30 June 2003.
[38] Peters, Janet. Hollywood Image. From the American Society of Mechanical Engineers Internet Website. www.asme.org. Accessed 6 August 2003.
[39] Tosti-Lane, Dave. How I Learned to Relax and Enjoy the Upgrade.
[40] National Academy of Engineering. Raising Public Awareness of Engineering. The National Academies Press. Washington, D.C. 2002.

Grades 6-8: A Visible Gap

Quality of education appears to become the problem in middle school, or grades 6-8. It is during this time that students begin to lose interest in math, for various reasons.[41] Students talented and interested in science begin to consider medicine or other scientific fields as an option, but rarely engineering. Teachers begin, purposely or not, to allow those students who do not excel in math to fall behind, resulting in disinterest by the time students reach 8th grade, although they continue to perform at fairly acceptable levels.[42] It is in these middle years that students fall behind in their preparation for higher mathematics and sciences, and begin to experience a lack of support to pursue these studies.[43]

Grades 9-12: Necessary Requisite Knowledge

High school, grades 9-12, is also a very important time to influence school children to pursue engineering. It is during these years that students begin to seriously consider their career path while applying for college and scholarships. A strong emphasis in math and science is necessary to prepare students for engineering curriculums, and usually necessary as prerequisites of university programs. Yet studies have concluded that only 15% of United States high school graduates possess these math and science requisites.[44] This lack of preparation is possibly a key factor in finding a solution to the problem, as students who may be interested in pursuing engineering, are turned away simply because they were not prepared.

Focusing on math and science education, even engineering and technology, on the PreK-12 level is highly important to the advancement of the American society and economy. It has become socially acceptable for students to graduate from high school lacking basic mathematics skills or scientific knowledge; yet poor English skills are looked down upon so severely they may hinder career advancement. Around 60% of

[41] National Academy of Engineering. Raising Public Awareness of Engineering. The National Academies Press. Washington, D.C. 2002.
[42] Clewell, Beatriz and Patricia Campbell. Taking Stock: Where We've Been, Where We Are, Where We're Going. Begell House, Inc. 2002.
[43] U.S. Department of Education. Mathematics and Science Initiative Concept Paper 5/15/2003
[44] Noeth, Richard; Cruce, Ty; Harmston, Matt. Maintaining a Strong Engineering Workforce. ACT Policy Report. 2003.

Americans have little idea of who an engineer is or what an engineer does.[45] It is vital that the government take action to create a well informed citizenry and government to keep up with ever changing new technology, and the first logical step to this is through education on a K-12 basis.

[45] National Academy of Engineering. Raising Public Awareness of Engineering. The National Academies Press. Washington, D.C. 2002.

Current National Policy

H.R. 1 The No Child Left Behind Act of 2001

"We believe education is a national priority and a local responsibility" President George W. Bush.[46]

This is the idea behind President Bush's No Child Left Behind Act (H.R. 1), passed by the U.S. House of Representatives on December 13, 2001 by an overwhelming bipartisan vote of 381-41.[47] Designed as a "comprehensive overhaul of the 1965 Elementary and Secondary Education Act (ESEA)", the law serves to provide choices for parents and flexibility for schools, districts and states, while requiring higher standards, and accountability for results.[48] The No Child Left Behind Act provides funding opportunities to place qualified, knowledgeable teachers in every classroom in America, potentially giving every child an equal opportunity to learn.

Title II, Part B: Mathematics and Science Partnerships

Under Title II, Part B of H.R. 1, $450 million were authorized for competitive 3-year grants to "partnerships for activities to improve the academic achievement of students in the areas of mathematics and science."[49] This section was designed to provide funding through grants for partnerships between primary and secondary schools and corporations, universities or organizations to increase overall student performance in mathematics and science. Successful grantees may use the funds for various purposes related to improving math and science education, from developing or redesigning more

[46] President Bush, George W. No Child Left Behind Website. http://www.nclb.gov/Newsletter/index.html Accessed 17 July 2003
[47] Website for the U.S. House of Representatives Committee on Education and the Workforce. No Child Left Behind Implementation Station. http://edworkforce.house.gov/issues/108th/education/nclb/nclb.htm Accessed 18 July 2003.
[48] iBid.
[49] Website for the U.S. Department of Education. The No Child Left Behind Act of 2001 Preliminary Overview of Programs and Changes. http://www.ed.gov/offices/OESE/esea/progsum/math Accessed 21 July 2003.

rigorous math and science curricula, to improving teacher preparation, recruitment and retention tactics, to programs that promote strong teaching skills.[50]

Improving Math and Science Achievement

As part of the U.S. Department of Education's goals related to the No Child Left Behind Act, studies have been conducted to improve math and science achievement. The Department of Education sees the fact that "America's schools are not producing the math excellence required for global economic leadership and homeland security in the 21st century" as the challenge.[51] According to the studies, math and science are critical skills in the information age, and the US "must improve achievement to maintain our economic leadership".[52] The perceived solution to the challenge is to "ensure schools use scientifically based methods with long-term records of success to teach math (and science) and measure (results)."[53] It's also necessary for partnerships to be established between K-12 schools, and universities to ensure teachers are prepared with the proper knowledge to provide the best instruction in their field.

The No Child Left Behind Act opens doors for the federal government to regulate standards while allowing flexibility on a local level. The flexibility is necessary to ensure schools have the opportunity to use methods most appropriate for their demographic, while the accountability standards ensure educational success across the nation.[54] The Department of Education calls for research to be done to discover the best methods for teaching math and science and measuring student success. This research has been successfully conducted for reading over the past decade, and must be done to aide in the success of individual state programs. This means utilizing programs with proven success, and eliminating those that are stale, unproven fads.[55]

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[50] Website for the U.S. Department of Education. The No Child Left Behind Act of 2001 Preliminary Overview of Programs and Changes. http://www.ed.gov/offices/OESE/esea/progsum/math Accessed 21 July 2003.
[51] Website for the U.S. Department of Education. The Facts About…Math Achievement. http://www.nclb.gov/start/facts/math.html Accessed 21 July 2003
[52] iBid.
[53] iBid.
[54] Hammond, Peirce. U.S. Department of Education. Personal Communication. 23 July 24, 2003.
[55] Website for the U.S. Department of Education. The Facts About…Math Achievement. http://www.nclb.gov/start/facts/math.html Accessed 21 July 2003

H.R. 438 The Teacher Recruitment and Retention Act of 2003

"The Teacher Recruitment and Retention Act is simple in its purpose and structure, but monumental in its potential to improve the lives of the nation's students…By giving highly qualified math (and) science…teachers a real financial incentive to teach in schools serving disadvantaged students, we have an opportunity to ensure that no child in America is left behind." Representative John Boehner of Ohio summed up the goal behind H.R. 438 with this quote.[56] The bill provides up to $17,500 in loan forgiveness to math and science teachers who agree to teach in low-income districts. The teachers must agree to teach for five years, with payments on the loans beginning after the second year.

The bill was established after research concluded that math, science and special education subjects face teacher shortages as high as 95%.[57] By offering loan forgiveness, the bill aims to attract early or mid-career professionals and graduates of STEM university programs, a difficult task as schools face heavy competition from the private sector, both education and the corporate world. According to California Representative Howard P. "Buck" McKeon, Chair of the 21st Century Competitiveness Committee, "There is widespread awareness that the subject matter knowledge and teaching skills of teachers play a central role in the success of elementary and secondary education reform." [58] As the US expects nearly 2.2 million new teachers to be required in the next ten years, with more than half being first time teachers, Congressman McKeon feels there should be an emphasis placed on improving teachers' preparation for the challenges of today's classrooms. It is for these reasons McKeon feels it is necessary that institutes of higher education take steps towards "ensuring that new teachers have the content knowledge and teaching skills they need to ensure that all students are held to higher standards."[59] As stated by Representative Joe Wilson of South Carolina: "I look forward

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[56] Boehner, John. House Approves Bills to Help States & Schools Put a Qualified Teacher in Every Classroom. News from the Committee on Education and the Workforce Website. http://edworkforce.house.gov/press/press108/07jul/teachersph070903.htm

[57] Congressman Joe Wilson's Internet Website. House Passes Wilson Bill to Recruit and Retain Teachers in Critical Subjects. http://joewilson.house.gov/News/DocumentSingle.aspx?DocumentID=727 Accessed 18 July 24, 2003.

[58] McKeon, Howard P. House Approves Bills to Help States & Schools Put a Qualified Teacher in Every Classroom. News from the Committee on Education and the Workforce Website. http://edworkforce.house.gov/press/press108/07jul/teachersph070903.htm

[59] iBid.

to the day when a new cohort of teachers begins its career teaching knowing each of them are part of a national program designed to prepare all children for a job market reliant on math and science sills."[60]

Previous Studies

National Science Foundation

In Fiscal Year 2002, the National Science Foundation (NSF) and the United States Department of Education established the Mathematics and Science Partnerships Program to fund partnerships between agencies and institutions targeted at improving instruction and strengthening student learning in mathematics and science. Since 1980, NSF has been involved in research to increase interest in engineering, and has promoted solutions through investments in curriculum development, pre-service and in-service teacher education, the informal science infrastructure, and uses of technology to enhance K-12 instruction and the creation of systemic reform.[61]

Math and Science Initiative

The findings of the NSF research have led them to make several recommendations, and guidelines for funding of programs. There is still much uncertainty as to how to improve mathematics and science achievement for all students. For this reason, they were supportive of the Department of Education's launch of a major five-year Mathematics and Science Initiative, which has three main goals:

1. **Conducting a broad-based public engagement campaign that draws attention to the need for mathematics and science education in our nation's schools.**[62]

[60] Wilson, Joe. House Approves Bills to Help States & Schools Put a Qualified Teacher in Every Classroom. News from the Committee on Education and the Workforce Website. http://edworkforce.house.gov/press/press108/07jul/teachersph070903.htm
[61] U.S. Department of Education. Mathematics and Science Initiative Concept Paper 5/15/2003
[62] iBid.

Citizens must be made aware of the problem at hand, and experience the opportunity to learn more about fields involving engineering, technology and science. Students need to be presented with role models so they can envision the career possibilities made available through advanced STEM[63] education. And parents need to be made aware that they may not have found technology and advanced math knowledge to be necessary in their career paths, but that their children will in order to be successful in a world that requires such abilities. The Initiative is working with the business community, professional organizations, and educators to sponsor events and mentoring programs (for both students and teachers) with the goal of exciting students and providing STEM examples to teachers.

2. **Initiating a major campaign to recruit, prepare, train, and retain teachers with strong backgrounds in mathematics and science.**[64]

It is necessary that the number of teachers with backgrounds in mathematics and science increase. Achieving this increase is possible through recruitment of teachers already possessing this knowledge, retaining effective teachers in the subject, or through improved training efforts to inform and update teachers. The United States Department of Education (ED) has existing federal programs that bring highly qualified recent college graduates and mid-career professionals with strong science, technology, engineering, and mathematics subject matter backgrounds into teaching.[65] There are also professional development programs in place that develop content knowledge for current mathematics and science teachers, and programs with incentives and improved working conditions established to retain highly qualified teachers. The Initiative will also focus on coordination between institutions of higher education and teacher training programs to ensure that K-12 mathematics and science teachers possess the high levels of content knowledge needed for the 21st Century.

[63] STEM – Science, technology, engineering, and mathematics.
[64] U.S. Department of Education. Mathematics and Science Initiative Concept Paper 5/15/2003
[65] U.S. Department of Education. Mathematics and Science Initiative Concept Paper 5/15/2003

3. **Developing a major academic research base to improve our knowledge of what boosts student learning in mathematics and science in the classroom.**[66]

As the problem seems to be an issue of bringing students in less privileged school districts up to par with those more affluent areas of the nation, research is being done to discover the best methods for teaching math and science to all students, from diverse backgrounds and cultures. The Initiative will seek out knowledge about the learning processes that are essential for a wide range of learners to be successful in STEM studies.

Overviews of Established Programs

The research conducted by NSF has found some programs experiencing small scale successes, but several unsuccessful attempts have been studied as well. The following are case studies of established programs, some more successful than others, created through state initiatives, or by universities, organizations and corporations.

State Programs

Several states have established various programs for improving student performance in STEM studies. From increasing computer literacy to changing curriculums, steps have been taken across the nation to improve STEM performance on a K-12 level. The most common reason for involvement on a state government level is due to economic concern. State officials are aware of the world's trend towards more technologically based lifestyles, and understand that their own region's success lies in the technological know-how of their citizens.[67] Another critical factor is that financial decisions are often based on performance. With the No Child Left Behind Act, continued funding depends on the measured success of various programs through testing. State officials depend on the success of their school-aged citizens to bring funding to their programs.

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[66] U.S. Department of Education. Mathematics and Science Initiative Concept Paper 5/15/2003

[67] Werwa, Eric. Legislative Director, Office of Congressman Honda, California. Personal communication. 30 June 2003.

Maine: Computers for all Students

The state of Maine has begun a ground breaking middle school education reform program. In 2002, every 7th grade student in the public school system received Apple iBook Wireless Computers and all 7th grade classrooms in the state public school system were wired for the wireless technology. [68] The program started out with a trial session, using nine middle schools as demonstration sites.[69] The usual middle school curriculum format has seen dramatic changes in these nine schools, where teachers were trained on integrating the computers into their everyday lessons, from math to science to art. The children were learning to use computer technology to conduct research, keep up with current events, and make presentations using Powerpoint and even computer video. The program was developed using the experiences and feedback of the teachers and students of these demonstration schools.

The goal of the program, as presented by Maine Governor Angus S. King, Jr., is to "ensure that Maine's students become the most technologically savvy students in the world".[70] While his deeper goal is on a regional economic base, hoping to attract more technological companies to the rural state of Maine, this competition between states is healthy and necessary, as the driving force behind all government decisions is financing. If the taxpayers and legislators of Maine see improving K-12 technological literacy as a key ingredient to future economic prosperity, the money will be allocated. This program is introducing students at an impressionable age to the many opportunities of technology. Students with hands on experience using technological tools will be better prepared to handle the rigors of engineering curriculums. Several states and countries have begun to imitate the program established in Maine, leading to a greater number of computer literate American and international students. The program is run by the Maine Learning Technology Initiative (MLTI), directed by Susan A. Gendron, Commissioner of Education.[71]

As discussed earlier, the importance of creating a technological literate population lies in the increased presence of mainstream technology companies in the state of Maine.

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[68] Maine Learning Technology Initiative Internet Website. http://www.state.me.us/mlte/ Accessed 1 July 2003.
[69] iBid.
[70] King, Angus, Jr. Correspondence from Gov. King to Rep. Allen. 4 April 2002.
[71] iBid.

It is for this reason that the state sought funding on a national level. Maine Governor Angus S. King Jr. sought aide federally with help from Maine's federal congressmen. In a letter sent to Congressman Tom Allen, representing the first district of Maine, the governor asked for federal funding of $10,000,000 in fiscal year 2002-03 to proceed with the program past the initial stages of 7th grade.[72] The request was successful and was funded as a national pilot program that will "increase student motivation and achievement, while assessing knowledge and skill against rigorous standards."[73]

While the state of Maine appears to have its chips in order to proceed with this project, there are still several valid concerns. The success of the program appears to vary drastically from school to school. Very few schools allow the children to take the computers home, where they could use the computers for homework or additional research for school projects. Children have stated that many teachers don't incorporate the computers into lesson plans.[74] And there is the ever lurking state budget crunch, bringing skepticism from Maine residents regarding the importance of giving computers to all students. Thus, while the demonstration schools were able to show the potential for the program, the reality is that several schools experience lack of training for teachers, guidance for new curriculums utilizing the technology, and confidence in the children's responsibility of toting the computers to and from school.[75]

Another major concern is the success of integrating the 7th and 8th grade students into the high schools, where their elder classmates will not have had the introduction to the technology. Mixed classrooms can not utilize the computers as some students will not only lack the equipment, but the experience as well. There is the additional financial burden of wiring entire high school buildings, and training high school teachers.

There are several hurdles presented to the true success of this program, but the leadership of the state of Maine seems ready to attack the challenge. The money is in place, the success cases of the demonstration schools act as inspiration, and the goal of creating a technologically advanced graduate class is in sight.

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[72] King, Angus, Jr. Correspondence from Gov. King to Rep. Allen. 4 April 2002.
[73] Nadzo, Anne. Legislative Assistant, Office of Congressman Thomas H. Allen, Maine. Personal communication. 1 July 2003.
[74] iBid.
[75] iBid.

Massachusetts: Science, Technology and Engineering Testing

After the creation of H.R. 1 The No Child Left Behind Act, states began to implement the necessary testing of their students. The state of Massachusetts has a pilot program in place to begin testing all students for engineering and technology knowledge. As regulated by NCLB, students are tested for different curriculum frameworks at three different levels: Grades 3-5, 6-8, and 9-12.[76] The Massachusetts Department of Education has broken the curriculums for these levels into several frameworks, including math, history, English, and several others. Science, technology and engineering have been grouped together into one curriculum framework for testing purposes in the 3-5 and 6-8 grade levels.[77]

For both the grades 3-5 and 6-8 testing requirements, the engineering and technology subjects are included as 25% of the science exam. In grades 3-5 the students are tested on engineering design and materials and tools as part of their science examination. Technology relating to machines, communications, manufacturing, transportation and bioengineering are added to the science tests in grades 6-8. In the high school testing period, technology relating to construction, energy and power, fluids, thermal systems and electronics are also added to the exam, which is no longer part of the science test. Not all students are required to take the exam, as it is separate. This exam is the most novel of the Massachusetts frameworks, and state officials are working on proposals to allow testing for these subjects at the ninth grade level, rather than the tenth grade level as required by NCLB.[78]

The intention of the Department of Education is that these subjects be taught to the students through year long courses at the high school level. However, studies are finding that curriculums are being designed to include tidbits of the engineering and technology exams throughout other courses. Examples are teaching engineering design through auto shop, communications technology through computer courses, and

[76] NCLB – No Child Left Behind. Bowler, Catherine. Massachusetts Department of Education, Technology and Engineering Curriculum Framework. Personal Communication. 15 July 2003.
[77] Bowler, Catherine. Massachusetts Department of Education, Technology and Engineering Curriculum Framework. Personal Communication. 15 July 2003.
[78] Bowler, Catherine. Massachusetts Department of Education, Technology and Engineering Curriculum Framework. Personal Communication. 15 July 2003.

construction technology during architecture courses.[79] As the high school level testing of these subjects is very new, conclusions can not be made regarding the success of pulling knowledge from several classes is any less informative than teaching through separate courses.

Catherine Bowler or the Science and Engineering Framework of the Massachusetts Department of Education points out the uniqueness of the Massachusetts testing program, as it is the only state to require all students be tested in technology and engineering at the fifth and eighth grade levels.[80] While this is true, the Department of Education does not regulate how the students are introduced to the subject matter, and does not aide in communication between schools with curriculum changes in place. Also of significance, is that schools decide which tests to give their students. While the tests have been created for discovering the knowledge level of engineering and technology among Massachusetts high school students, the accountability of actually teaching the subject matter has not been established.[81]

California: Tax Break Incentives

The state of California has taken a similar approach to introducing their students to the world of technology, but on a much smaller scale. The California government has passed a law providing tax breaks to citizens and corporations who donate computers to schools or organizations. The goal of the program is to increase the number of California residents with computer access and literacy.[82]

The program has met several speed bumps, the largest of which being the quality of computers. The majority of the computers donated through the program are of inferior quality, old and abused, on their way out because they are being replaced with current technology. This does not help to meet the goal of the program, as those students using these computers are not receiving the best possible experience, but instead an out of date look at technology.

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[79] Bowler, Catherine. Massachusetts Department of Education, Technology and Engineering Curriculum Framework. Personal Communication. 15 July 2003.
[80] iBid.
[81] Bowler, Catherine. Massachusetts Department of Education, Technology and Engineering Curriculum Framework. Personal Communication. 15 July 2003.
[82] Werwa, Eric. Legislative Assistant, Office of Congressman Honda, California. Personal communication. 30 June 2003

University Programs

Several universities across the nation have developed programs targeted at introducing students to the world of engineering and technology. While most programs are developed with the intent of spreading recognition for the given institution, they serve to increase student interest in engineering, as well as improve teacher and parent involvement in encouraging students to pursue engineering. Schools like the Colorado School of Mines in Golden, Colorado, have camps for high school students to gain a general understanding of the engineering curriculum. Other schools, such as the Worchester Polytechnic Institute in Worchester, Massachusetts, help develop curriculums for K-12 students to experience engineering and technology first hand.[83] The Institute for Engineering Education has been developed at Southern Methodist University in Dallas, Texas, to involve the community in introducing all people, regardless of demographic, to the opportunities available through technology and engineering.[84]

The Institute for Engineering Education at SMU

A mostly successful case available is that of the efforts of the Institute for Engineering Education at Southern Methodist University in Dallas, Texas. Under the direction of Geoffrey Orsak, Ph.D., SMU School of Engineering Associate Dean, Research and Development, and Executive Director for the Institute, the program has made significant steps in increasing interest in engineering locally, and even nationally. There are several branches of the Institute, most notably Visioneering and the Infinity Project.

Visioneering

Visioneering is an annual one day event, held during National Engineers Week, targeted at middle and high school students in the Dallas/Fort Worth metroplex. Most participants are public school children who give up their entire Saturday to learn and experience engineering and technology and the roll engineering plays in their future. In

[83] Bowler, Catherine. Massachusetts Department of Education, Technology and Engineering Curriculum Framework. Personal Communication. 15 July 2003.
[84] Internet Website for the Institute for Engineering Education. http://theinstitute.smu.edu Accessed 20 July 2003

just three years the program has become an event that hosts 500 student participants.[85] During the course of the day, the students hear from students of SMU's School of Engineering who are athletes and school and community leaders pursuing engineering degrees. They also hear from professional athletes, business moguls, and government officials encouraging the children to consider engineering as their future. Such role models as Mark Cuban, Jack Kilby, and Miss Teen Texas (an electrical engineering student) have shared their thoughts and words of wisdom.

All of these talks are given in a high-tech, "MTV™" style arena which incorporates TVs, lasers, lighting and sound systems to involve the students and make the event high-tech, energetic and fun. Following these events, the children break into assigned teams, led by SMU students and working engineers, where they work on a design project. The theme for the design project changes each year, and focuses on a product of the future. The past three years have seen "Designing the Computer of the Future", "Designing the Transportation System of the Future", and "Designing the Emergency Room of the Future" as themes. Each design team is judged and awards are presented at the end of the day. The event also includes a tech expo showcasing the latest technologies from the nation's leading engineering and technology companies, where the students make webpages, control robots, and experience engineering hands on.[86]

The Infinity Project

The most effective initiative of the Institute is the Infinity Project Engineering and Technology curriculum for 10th through 12th grade students. There are over 60 schools in 21 states, including the District of Columbia, currently utilizing the course as a math credit for graduation requirements.[87] The target of the course is to introduce students to the study of technology in a hands on environment. The 528 page text book for the curriculum covers such topics as digital music and images, communication with ones and zeros, and the world of modern engineering.

For a school to bring the Infinity Project into their curriculum, they must apply to the Institute for Engineering Education. The school must have an appointed teacher for

[85] Information received via e-mail from SMU Visioneering Staff. Received 21 July 2003.
[86] Visioneering Website http://www.theinstitute.smu.edu/visioneering.html Accessed 24 July 2003.
[87] iBid

the course, who has the opportunity to travel to Dallas to participate in a one week "Boot Camp" to cover the training for teaching the course successfully. Regardless of traveling to Dallas, the teachers are supplemented with extensive training materials, and the children are reaping the benefits. The appeal of the class varies, but the key draws seem to be the chance to learn about "cool" technology such as cell phones and video games while receiving credit towards math requirements for graduation. The only pre-requisites for the course are high school algebra II and at least one science course.

As the Infinity Project is a fairly young program, long term results are not available. However, the students taking the courses talk of no previous knowledge of the world of engineering, and now consider pursuing engineering degrees in college.[88] While the numbers are not yet available to prove success, this program seems to be making the desired impact on high school students, interesting them in technology and encouraging them to grow up to be engineers.

Organizational Programs

Organizations of engineering professionals have also become highly involved in efforts to better prepare students for engineering and technology curriculums. Many do so because of their role as coordinator between several member organizations, such as the World in Motion program by the Society of Automotive Engineers.[89] Other organizations aim to increase certain demographics in the engineering field, such as the Society of Women Engineers and their efforts with the Girl Scouts of America. Regardless of the purpose of the efforts made by these various organizations, the results remain the same. Students across America are learning about the various opportunities available in engineering and technology and realizing the importance of being prepared in math and science.

Society of Women Engineers: Girl Scout Outreach

The Society of Women Engineers, SWE, has been involved with the Girl Scouts of America, Inc. for several years, helping girls to receive technology and engineering

[88] Infinity Project Staff. Personal Communication regarding student surveys. 18 July 2003.
[89] Read, Doug. Society of Automotive Engineers. Personal communication. 23 July 2003.

badges. SWE interacts with the Girl Scout troops on a local level, providing locations and supplies for entire workshops in some cases. An effort to create a formal relationship between the organizations is underway.

Society of Automotive Engineers, Inc.

The Society of Automotive Engineers, Inc. developed a program for grades 4 through middle school students entitled "A World in Motion: The Design Experience".[90] The program is comprised of three challenges. Challenge 1, for students in grades 4, 5 and 6, is emphasizes hands-on discovery of science principles. With the aid of AWIM kits that include lesson plans and instructional materials for teachers, as well as equipment for thirty students to build jet toys, skimmer boats, or steel can rovers.[91] Challenge 2, for middle school students, is an eight week course challenging students to work in engineering design teams to build a motorized toy vehicle. Challenge 3, also for middle school students, is an intense exploration of flight as students design a glider and present it to local press and members of their communities. All of the challenges succeed with the help of professional engineer volunteers and donations from partnering corporations.

The National Science Foundation funded the development of the program, and continued distribution of kits is handled by the Society of Automotive Engineers and corporate and individual contributors. The program is successful due to its continuous funding and integration of all subjects. Edith Roos, a teacher in Helena, Montana at Helena Middle School uses the AWIM: Challenge 2 kits in her classroom. She "loved the toy unit because of the potential for lots of integration with other subjects…[she] loved the engagement of the students, their enthusiasm. Their parents loved it too because students came home from school and actually talked about what they did that day".[92] The World in Motion program is introducing students to the world of engineering, exciting them and turning them on to the many possibilities that engineering can offer.

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[90] SAE Foundation for Science and Technology Education. Pamphlet for A World In Motion: The Design Experience.
[91] iBid.
[92] iBid.

Industry

The industry sector has long been involved in encouraging young people to pursue the technical fields. Those companies that depend on engineering students graduating from American universities take interest in ensuring students are on the right track to enter the universities in the first place. Several companies get involved through sponsorships of programs such as the World in Motion or Infinity Project programs described earlier. Others create their own programs. The common factor is the support that industry provides to programs encouraging students to become more technologically literate and knowledgeable for the information age.

IBM: Preschool Classroom Technology

IBM has taken action at the preschool level, bringing the Young Explorer computer learning center to preschool classrooms across the country, as part of its KidSmart Early Learning program.[93] The goal of the program is to introduce all children, regardless of their family's income situation, to the technology of computers. IBM is giving children of low-income families the opportunity to be comfortable with technology when they reach elementary school, just as their counterparts whose families have computers in their homes. IBM looks at technology as a tool to address societal issues, and they are using it to do exactly that.[94]

Lockheed Martin: Community Outreach

Through various initiatives across the nation, Lockheed Martin has aimed to spark young students' natural curiosity and encourage their interest in math and science.[95] Lockheed Martin has joined the University of Tennessee in the creation of intensive training programs for K-12 educators, and partnered with the Maryland Business Roundtable for Education in moving the state of Maryland into the national forefront of standards-based school reform. The reason for Lockheed Martin's investment in math

[93] IBM Internet Website. http://www.ibm.com/ibm/ibmgives/grant/education/programs/kidsmart.shtml Accessed 14 July 2003.
[94] iBid.
[95] Lockheed Martin Internet Website. http://www.lockheedmartin.com/about/community_relations/k-12.html. Accessed 14 July 2003.

and science education is that they "recognize its centrality to the future of [their] industry, our economy and our society."[96] Across the nation, Lockheed Martin has partnered locally to contribute to the mathematical and scientific success of our nation's school children.

Collective Results

Common Difficulties Encountered

Funding

While there are many programs with the potential to be successful, none can survive without financial support. Outreach programs and curriculum changes are developed on a regular basis, but the initial funding is often not followed by continuous support, and the programs die away before they make any measurable impact. Another problem is that schools without evident success stories find receiving initial funding to be difficult. The National Science Foundation has established grant opportunities to encourage schools and districts to experiment with new programs for encouraging STEM subject matter. In the state of California, however, several schools apply to the grants, but usually the schools with established programs already making a difference win new money to try newer, better things. The schools that are in desperate need of success in basic STEM programs never see the money, while the schools receiving finances continue to improve.[97]

The idea of financial inequality among schools is a recurring concern. Depending on location, federal funding spent on education in our nation varies from as little as $2,000 per child per year, to as high as $15,000.[98] The office of Massachusetts Senator Kerry points out that it would be beneficial to the goal of increasing preparedness of students for engineering if the federal government became financially involved in those

[96] Lockheed Martin Internet Website. http://www.lockheedmartin.com/about/community_relations/k-12.html. Accessed 14 July 2003.
[97] Werwa, Eric. Legislative Assistant, Office of Congressman Honda, California. Personal communication. 30 June 2003.
[98] Hunter, Jaime. Legislative Director to Senator John Kerry, Massachusetts. Personal Communication. 2 July 2003.

schools in the lower end of this spectrum.[99] The schools with more money have the financial opportunity to provide high-tech, hands-on experience in science and math, preparing their students for future success. Senator Kerry's office expressed concern that the federal government does not show enough commitment to the sciences, or that it is not reacting quickly enough for today's fast moving technology.[100]

While the No Child Left Behind Act of 2001 provides more money for successful programs, it does not guarantee children will experience increased instruction in STEM disciplines. The specific allocations of the money are regulated locally, and it is up to local officials to decide where the educational need lies. Even if the schools do receive support for STEM programs, continued success relies on future funding by the next congress.[101]

Teaching Issues

Quality, training, knowledge, and just plain volume of teachers are all obstacles for improved STEM education. This is a major concern, as the success of any school program relies on the abilities of the teachers. With the No Child Left Behind Act and all of the legislation resulting afterwards, expectations have been set to increase teacher quality across the nation.[102] This legislation stemmed from facts such as that in 2001, 33% of U.S. middle school math and science teachers were not certified to teach their assigned subjects.[103] While there are many ideas for improving teacher knowledge, the bigger issue is the foreseen lack of teachers in the next 10 years.

Studies suggest that nearly 2.2 million new teachers will be needed in the U.S. alone in the next decade.[104] The statistics also show, however, that U.S. college of education will not be graduating nearly enough students to fill this expected demand. Additionally, those graduates with degrees in science, technology, engineering and

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[99] Hunter, Jaime. Legislative Director to Senator John Kerry, Massachusetts. Personal Communication. 2 July 2003.
[100] iBid.
[101] Werwa, Eric. Legislative Assistant, Office of Congressman Honda, California. Personal communication. 30 June 2003.
[102] H.R. 1 The No Child Left Behind Act, H.R. 438 The Teacher Recruitment and Retention Act.
[103] American Society of Mechanical Engineers. Position Statement – 2003 ID #03-27 Support for Teacher Loan Forgiveness. 26 June 2003. http://www.asme.org/gric/ps/2003/03-27.html Accessed 14 July 2003.
[104] American Society of Mechanical Engineers. Improving K-12 Science, Technology, Engineering, And Mathematics Education: Options for State Legislatures. November 2002.

mathematics are pursued by the private sector, and higher salaries lure them away from pursuing teaching careers.[105] In order to expect improvement of the nation's students in STEM related studies, the nation must do something to improve the teaching situation first.

Lack of Guidelines for Measurement of Success

What makes a program "successful"? What makes it a "failure"? There are no standards in place to measure the success of any of the discussed programs.[106] Several institutions and organizations rely on feedback from volunteers and participants to show the success of their program. This works for improving their specific program from year to year, but it does not lead to national solutions. If programs are going to grow bigger than the grass-roots level, a common set of standards for successful engineering-preparation programs must be established.[107]

Common Successes

Mandatory Curriculums and Events

By creating events and curriculums that are mandatory, all students experience the same introduction to engineering and technology. The state of Maine evened out the playing field for all students by providing computers, and therefore preparing students for the high-tech world they will move into upon graduation. The same goes for the schools utilizing the IBM Young Explorer computer centers. The children using these computers are all on the same level technologically, regardless of their financial situation at home allowing for computers or not.

Hands-on, "Cool" Events

One major advantage to teaching engineering and technology to young kids is that they are not subjects that need to be "made interesting" because they already are on their

[105] American Society of Mechanical Engineers. Improving K-12 Science, Technology, Engineering, And Mathematics Education: Options for State Legislatures. November 2002.
[106] Based on the programs investigated in this report.
[107] Hunter, Jaime. Legislative Director to Senator John Kerry, Massachusetts. Personal Communication. 2 July 2003.

own.[108] What is necessary is that the subjects be toned down to the appropriate detail for different age groups, as to not overwhelm students with equations and concepts before ever getting a hands-on experience. It is this concept that makes the discussed programs successful. K-12 students enjoy the experience of sitting in front of a computer, learning about all that possibilities through technology. The SAE World in Motion project gives kids the chance to see engineering from the birth of a design to the final conception of the product. Children enjoy the feeling of accomplishment, and enjoy discussing their school day with their parents.[109] These programs are planting seeds of curiosity and excitement in the minds of the children.

[108] Werwa, Eric. Legislative Assistant, Office of Congressman Honda, California. Personal communication. 30 June 2003.
[109] SAE Foundation for Science and Technology Education. Pamphlet for A World In Motion: The Design Experience.

CONCLUSIONS: IMPROVING THE NUMBER OF ENGINEERING STUDENTS

Improving Student Interest

The Necessary Paradigm Shift

It appears a paradigm shift is necessary. Engineering is widely perceived as a field that focuses only on math and science. Students who are not superior in these subjects are scared away by the overwhelming theories and equations.[110] Often, students that possess the talents to succeed at the mathematical level required in engineering curriculums, feel that they are more creative than analytical, and that engineering would not allow them to exercise their creative abilities.[111] What is not considered is that engineering is perhaps one of the best places to utilize creativity. Everyday engineers are creating new processes, products and designs. As Texas Representative Hall points out "engineers are good at looking to the future".[112] Anything imaginable is likely possible through engineering. Children need to be introduced to this concept early on, to experience the crossroads of creativity and technology. This may be possible through an integration of the arts and math, science and technology.

Improved Presentation Methods

Music class, for instance, provides the opportunity to show children this mixture of disciplines. The composition of a musical score is highly mathematical. The way in which music travels from the instrument to the human ear is scientific. And the recording of music is possible today through technology. Even beyond recording, music is now being digitally prepared and created. Programs for composers allow musicians to sit at the computer and create, through trial and error, a score for a philharmonic orchestra without the presence of a single musical instrument. If these concepts are presented to children, they will see at an early age that they can combine their love of music with

[110] Werwa, Eric. Legislative Assistant, Office of Congressman Honda, California. Personal communication. 30 June 2003.
[111] Office of Congressman Breaux, Louisiana. Personal Communication. 30 July 2003.
[112] Hall, Ralph. U.S. House of Representatives. Texas, 4th District. Personal Communication. 24 July 2003.

technology through electrical or computer engineering. Another example is art class. A student who shows strength in math, but also has an eager interest in sculpture, should be introduced to mechanical, civil, architectural and structural engineering. With the analytical skills learned through engineering curriculums, brilliant pieces of art can be manipulated and constructed.

Improving Student Preparation

Improved STEM Learning

Studies conclude that most of the students graduating high school do not possess the requisite coursework to even apply to university programs of engineering. This is mostly due poor math and science preparation, and usually no technology or engineering. From changes in curriculum to improved teacher quality and teaching methods, there are many opportunities to advance the capabilities of American students.

Curriculum Changes

As mandatory engineering and technology curriculums are considered to be part of the solution, it makes sense to incorporate them into the nation's educational systems. The state of Massachusetts, without mandating specific lessons or coursework, has set up a framework for desired knowledge relating to engineering and technology based on grade level. By incorporating engineering ideas into science lessons in the Pre-Kindergarten through 6th grades, Massachusetts teachers are introducing their students to a whole new world of possibilities. With just the basic understanding of engineering and all that engineers do, students are drawn to courses offered in the upper-level grades. Ms. Barbara Bratzel, a teacher at Shady Hill School in Cambridge, Massachusetts, uses engineering in her physics classes, entitled "Physics by Design".[113] Hands-on experiences and the integration of technology and design into the everyday physics curriculum has students excited and recommending the course to their peers. The class

[113] 2001-2003 Center for Engineering Educational Outreach. http://www.prek-12engineering.org/default.asp Accessed 28 July 2003.

usually has more students register than there are spaces available.[114] It is courses like Ms. Bratzel's that need to be wide spread to improve the numbers of students pursuing engineering when they reach the collegiate level.

Teaching Quality

Ms. Bratzel brings a very important quality to her lessons: excitement about engineering. Too many U.S. teachers are not excited to be incorporating engineering and technology into their everyday coursework. Most teachers lack this excitement due to their low level of understanding engineering themselves. Teachers must be better trained and educated, so they are excited to pass on their knowledge.[115] Even Ms. Bratzel wishes that she had formal training in engineering.[116]

Organizations such as the American Society of Mechanical Engineers have published their recommendations for improving recruitment, training, and retention of qualified teachers.[117] Ideas range from differential pay scales to aide in the attraction and retention of qualified STEM teachers, to creating mentoring and shadowing programs between career engineers and STEM teachers.[118] A very simple solution is to include engineering and technology education in the university curriculum for those seeking education degrees.[119] Regardless of the methods used, teachers must be better educated to be able to encourage students to move on to engineering after high school graduation. It is necessary that they plant the curiosity into their students.

Mandatory high School STEM Curriculums

Programs such as the Infinity Project that incorporate engineering and technology into the regular high school curriculum are vital to prepare students for entering programs of engineering at the university level. These programs ensure students have an

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[114] 2001-2003 Center for Engineering Educational Outreach. http://www.prek-12engineering.org/default.asp Accessed 28 July 2003.
[115] Ehlers, Vernon. U.S. House of Representatives. Grand Rapids area of Michigan. Personal Communication. 30 June 2003.
[116] 2001-2003 Center for Engineering Educational Outreach. http://www.prek-12engineering.org/default.asp Accessed 28 July 2003.
[117] American Society of Mechanical Engineers. Improving K-12 Science, Technology, Engineering, And Mathematics Education: Options for State Legislatures. November 2002.
[118] iBid.
[119] iBid.

understanding of engineering and all it has to offer. Students that experience these courses learn about the career possibilities, imagine themselves there, and are more likely to enter into university degree programs for engineering or computer science.[120] Without these introductions, though, students are less capable of making the transition.

As U.S. K-12 performance in math and science is poor, students are not prepared to enter into the vigorous coursework of engineering programs. Only 11% of students complete the necessary math courses of algebra I, geometry, and algebra II.[121] By allowing these students to graduate with such little comprehension of basic math, teachers and administrators are closing doors to their students. It is common to require 4 years of English, but not math or science.[122] To fully prepare students to have the option of studying engineering, schools must begin to make sufficient science, technology, engineering and mathematics courses mandatory.

Improving the Number of Underrepresented Students: The Next Step

Through the investigation of the root causes for such low numbers of students entering collegiate engineering programs, it is impossible to ignore the blatant issue of underrepresented groups. Women and minorities only make up a combined 29% of students choosing to study engineering, and their attrition rate during the undergraduate degree years is higher than that of Caucasian males.[123] Various studies have been conducted to determine the possible solutions to these numbers. The extent of these studies is so large, that to delve into them is another research presentation of itself. Knowing the possible solutions for encouraging students of both genders and all races leads to possible mutations that will attract these underrepresented groups. The next step in improving student performance in K-12 STEM studies, while increasing their chances of becoming tomorrow's engineers, is to focus on the number of women and minorities represented in fields of engineering and technology.

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[120] Information received via e-mail from SMU Visioneering Staff. Received 21 July 2003.
[121] Noeth, Richard; Cruce, Ty; Harmston, Matt. Maintaining a Strong Engineering Workforce. ACT Policy Report. 2003.
[122] Information received via e-mail from SMU Visioneering Staff. Received 21 July 2003
[123] Clewell, Beatriz. Campbell, Patricia. Taking Stock: Where We've Been, Where We Are, Where We're Going. Begell House, Inc. 2002

RECOMMENDATIONS

Collective Successes to Create a National Program

With all of the grassroots successes experienced by these states, universities, organizations and corporations, the possibility arises of combining efforts to make one national program. The common program traits that seem to motivate and interest K-12 children are hands-on, high-tech, high-profile events that show the "cool" side of engineering. Programs such as Visioneering, IBM KidSmart, and SAE's A World in Motion all give the children a chance to experience engineering and technology in a hands-on, inquiry based setting. The key points of these programs that make them successful can be combined into one effort to be tackled nationally by all groups.

Increased Federal Funding

While there may be multiple opportunities and ideas present for improving the reputation of engineering, and creating interesting programs and curriculums for primary and secondary school children, the fundamental problem lies in funding. Traditionally, K-12 education has been the responsibility of state and local governments. The federal government has had little control over education on a national level and this must change if the situation is to improve.

Leveling the Playing Field

The first step to increasing the number of students capable of success in engineering programs is to level the playing field in our nation's primary and secondary educational institutions. The opportunity for the federal government to become involved is through fiscal means. If a set number of dollars was decided for the minimum to be spent per child in order to ensure a technologically advanced education, the federal government could aid communities unable to reach that value. The basis behind this idea is that schools in affluent communities, where students receive the necessary education to prepare them for success in engineering studies, are already above average in our nation. They are producing college engineering students at an acceptable rate. The schools that are not able to prepare their students due to lack of funds should be the priority in improving the numbers. If focus is given to these schools performing at substandard

levels, the number of students introduced to and interested in engineering and science fields will naturally increase. It is necessary to equalize funding for primary education.

Improved Teacher Quality

It is also necessary for the federal government to remain involved financially in the efforts to improve teacher quality. Students can not experience their best possible education opportunities without knowledgeable, well-trained teachers. Programs for the recruitment and retention of high quality teachers of STEM disciplines must remain in place and financially supported to ensure the success of American high school graduates. It is doubly important that the federal government step in fiscally during this economic downturn, as states are out of money to spend on improving education.

Federally Regulated Standards

From a different viewpoint, the federal government should be setting standards for education. There are approximately 2500 counties in the United States. For a single country to have 2500 different ways of teaching their youth is asinine. If the nation's leaders want to ensure our future prosperity, they must be concerned with the education of our future leaders. There are national standards and programs in place to ensure literacy, knowledge of our nation's history, and even elementary mathematics. It is necessary to set standards for courses relating to technology, science, engineering and advanced mathematics. Universities without internet networks are considered to be in the Stone Age, yet students are graduating high school with little to no knowledge of word processing, internet researching, and other important computer applications. There is a world of possibility for our young people once they have technological literacy. It should be a priority of our country to ensure our children are in the same position as children across the world. If we want to ensure our nation's security and economic competitiveness, we must encourage our young people to embrace technology and pursue careers in engineering.

Redefining the Engineer

Finally, it is necessary that Americans begin to recognize the numerous contributions of engineers to our society. Through public outreach to increase awareness of what engineers are and what they do, the public perception of the importance of engineers to the every day life of American citizens will improve. Teachers and parents will encourage children to pursue engineering and students will maintain interest and excitement in math, science, engineering and technology. Once this has been accomplished, the United States will see university programs of engineering enrollment numbers begin to increase, and the economic well being, national security, and standards of living in America will be secured by a technologically literate workforce.