Current Status of Engineering Education and ASEE

Ronald E. Barr

Professor of Mechanical Engineering
The University of Texas at Austin
and
ASEE President 2005-06

INTRODUCTION

Many faculty believe that engineering education in America is at a crossroads and much change is needed. International competition in engineering and the global economy have major potential impact on the engineering workforce of the future. We must find ways to educate U.S. engineers to be competitive and creative contributors in the worldwide arena. Recent national reports are sounding the alarm that the U.S. is losing it leadership in technology and innovation, with consequences for economic prosperity and national security. Changes in ABET accreditation, along with new paradigms of teaching and new technology in the classroom, are changing the scholarship of engineering education. We must find ways to promote change in engineering faculty for this new opportunity in engineering education. Future engineering students are now in K-12, which is becoming an increasingly diverse population that in the past has not been fully represented in engineering education. Current trends show disaffection for pursuing studies in science and engineering in the youth of our U.S. society. We must find new ways to portray engineering as an exciting and rewarding career, and certainly as an educational platform for diverse professional careers beyond the baccalaureate. These and other important topics of current interest in engineering education are briefly presented, and some of ASEE's responses in these venues are outlined.

GLOBAL ENGINEERING EDUCATION

The engineering landscape has changed in the past decade. As Thomas Friedman[1] has so profoundly stated in his contemporary book, the world is now flat. The implication of this concept is that routine engineering work, which was once performed by American engineers, is now being outsourced to international technology shops. Designing a circuit board or a new mechanical pump can now be adequately performed by "commodity engineers" in China or India, and at about one-fifth the labor costs of an American tech worker. The playing field is now level, and American engineers must offer better value, such as creativity, communication, and leadership skills, in the world employment market today.

This global competition has not happened by accident. Certainly the arrival of the internet ten years ago has hastened global engineering. For example, an engineering project or design idea can start in the United States at 8 am, be sent to Asia at 5 pm, and then downloaded to a European site at 12 midnight. Thus, the global engineering project is a 24/7 reality. But, it

Copyright © 2006, American Society for Engineering Education

is not just the internet that has created global competition in engineering. Other countries around the world have been ramping-up their science and engineering education output, while America has seen a decline. According to the NSF "Science and Engineering Indicators" report[2], the United States has experienced a decline in its science and engineering position in the world. Figure 1 shows a ratio of the number of science and engineering degrees earned by the 24-year-old population for various countries. What is startling about the data, which compares this ratio for the years 1975 and 2000, is the stark decline in the U.S. superiority in this ratio. In 1975, the United States and Japan ranked the highest, with ratios around 4.0 to 4.5. But by the year 2000, a quarter-century later, the U.S. is outranked by fourteen other countries in Europe and Southeast Asia, as well as Canada.

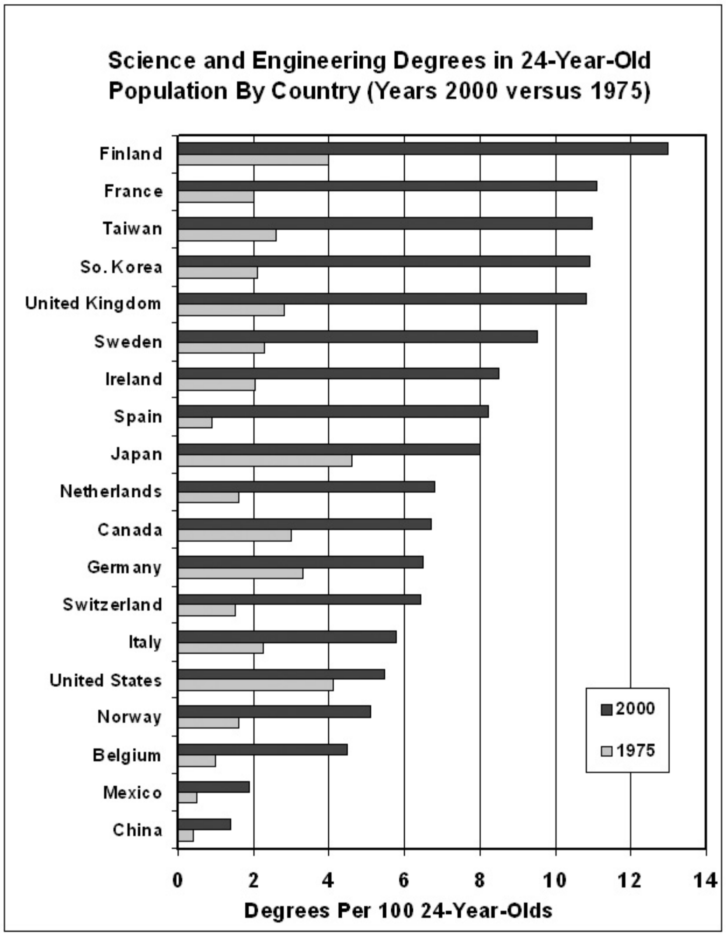


Figure 1. Science and Engineering Degrees in the 24-Year-Old Population. (*source: NSF, 2004*).

Another way to measure the progress of global engineering education is shown in Table 1. The table presents the total number of engineering degrees awarded by country and the percent of engineering degrees versus total college degrees awarded. While reliable statistics are difficult to ascertain, numbers published by Murray[3] indicate that engineering students are a small minority in U.S. colleges. In 2000, the figures showed that just 4.7 percent of U.S. undergraduate degrees went to engineers, while 38.7 percent of the undergraduate degrees in China were awarded to engineering students. Just in terms of raw numbers, the U.S. is way behind China, and also behind Japan in the data. Further note that data from India is difficult to get and is not reflected in Table 1. But, popular opinion is that India graduates around 250,000 engineers per year.

Assuming that science and engineering education strongly influence the economic prosperity and standard of living of a nation, the data does not bode well for America's future. Engineering education has shown a steady increase in America for the past 200 years. During this time the United States has become the greatest country in the history of civilization. It is incumbent on American engineering educators, and the engineering community as a whole, to address this global challenge and reverse the direction.

Table 1. University Degrees and Engineering Degrees (*from Murray, 2005).*

Country	University Degrees	Engineering Degrees	Percentage
China	567,839	219.563	38.7%
Taiwan	117,430	26,587	22.6%
Germany	178,618	36,319	20.3%
Japan	542,314	104,478	19.3%
France	275,316	34,293	12.4%
Ireland	18,669	2,014	10.8%
United Kingdom	274,440	20,280	7.4%
Kenya	15,620	740	4.7%
United States	1,253,121	59,536	4.7%

CONTEMPORARY ENGINEERING MANPOWER REPORTS

In recent years a number of studies have begun to sound the alarm that America is losing international leadership in engineering and technology. As a consequence, our future economic prosperity and national security are at risk. The findings and key recommendations of some of these reports are summarized next.

The Gathering Storm Report

The National Academies were asked by Senators Lamar Alexander and Jeff Bingaman to study ways to enhance the science and technology enterprise so that the U.S. can compete, prosper, and be secure in the global community. A 20 person committee was created, chaired by Norman Augustine, retired chairman and CEO of Lockheed Martin. The committee included current and former industry CEO's, university presidents, Nobel laureates, and former presidential appointees. The report[4], "Rising Above the Gathering Storm," included a list of both findings and recommendations.

Among the findings, the "Gathering Storm" committee reported that for the cost of one engineer in the United States, a company can hire about 11 engineers in India. Today, the U.S. is a net importer of high-technology products. Fewer than one-third of U.S. 4th grade and 8th grade students performed at or above a level called "proficient" in mathematics. In 2003, only three American companies ranked among the top 10 recipients of patents granted by the United States Patent Office. In 2004, China graduated over 600,000 engineers, India 350,000, and America about 70,000. Although many people assume that United States will always be a world leader in science and technology, these findings do not support that claim.

The recommendations reported in "Gathering Storm" are shown in Table 2. These included: A. federal commitment of funding for K-12 science and mathematics; B. increase federal funding on research; C. recruit the best and brightest scientists and engineers to work in the U.S.; and D. improve the U.S. infrastructure for new technology and innovation, including tax credits. The significance of the report is the detailed recommendations for U.S. investment to ensure these accomplishments over the next ten years (see Table 2).

Table 2: Recommendations from the “Gathering Storm” Report
A. Increase America’s talent pool by vastly improving K–12 science and mathematics education. A.1 Recruit 10,000 science and mathematics K-12 teachers by awarding 4-year college scholarships. A.2 Strengthen the skills of 250,000 teachers through training and education programs at summer institutes and in master’s programs. A.3 Enlarge the pipeline by increasing the number of students who take AP and IB science and mathematics courses.
B. Sustain and strengthen the nation’s traditional commitment to long-term basic research B.1 Increase the federal investment in long-term basic research by 10% a year over the next 7 years. B.2 Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of our most outstanding early-career researchers. B.3 Institute a National Coordination Office for Research Infrastructure B.4 Allocate at least 8% of the budgets of federal research agencies to discretionary funding B.5 Create in the Department of Energy (DOE) an organization like the Defense Advanced Research Projects Agency (DARPA) B.6 Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest.
C. Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers C.1 Increase the number and proportion of US citizens who earn physical-sciences, life-sciences, engineering, and mathematics bachelor’s degrees by providing 25,000 new 4-year competitive undergraduate scholarships each year to US citizens C.2 Increase the number of US citizens pursuing graduate study in “areas of national need” by funding 5,000 new graduate fellowships each year. C.3 Provide a federal tax credit to encourage employers to make continuing education available (either internally or though colleges and universities) to practicing scientists and engineers. C.4 Continue to improve visa processing for international students and scholars C.5 Provide a 1-year automatic visa extension to international students who receive doctorates or the equivalent in science, technology, engineering, mathematics, or other fields of national need C.6 Institute a new skills-based, preferential immigration option. C.7 Reform the current system of “deemed exports”
D. Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs that are based on innovation D.1 Enhance intellectual-property protection for the 21st century global economy D.2 Enact a stronger research and development tax credit to encourage private investment in innovation. D.3 Provide tax incentives for United States based innovation. D.4 Ensure ubiquitous broadband Internet access.

Business Roundtable Report

A group of 15 leading business organizations[5] joined together to issue a deep concern about the U.S. ability to sustain its scientific and technological superiority in the world. Their expressed goal is to double the number of science, technology, engineering, and mathematics (STEM) degrees in the U.S. by the year 2015. This goal comes as a result of alarming facts about STEM education in the U.S. Some of the troubling facts include:

- By 2010, if current trends continue, more than 90 percent of scientists and engineers in the world will live in Asia.

- More than 50 percent of engineering doctoral degrees awarded by U.S. colleges are to foreign nationals.
- The number of B.S. engineering degrees awarded in the U.S. is down by 20 percent from the peak year of 1985.
- China graduates four times as many engineers as the United States.
- Security concerns in the U.S. are limiting the world talent pool available to work in this country.
- Since 1970, the U.S. investment in basic research in the physical sciences has declined by half, as measured by percentage of the GDP.

In order to counter these trends, the Business Roundtable report gives five recommendations as shown in Table 3. These recommendations from the Business Roundtable agree with and even overlap the “Gathering Storm” report. So consensus is building for the same action items in America. The report also includes some excellent citations to support their claims. One that is worth noting is a statement that high school and college students need better information about the wide range of opportunities for STEM degrees. According to a citation from Fogg, et al.[6], “there is a high economic gain for an engineering degree even if a graduate works in a non-engineering field.” Thus, the idea of a “citizen engineer” (i.e. degreed engineers working as leaders and activists in diverse areas of the American culture) is worthy of consideration.

Table 3. Recommendations from the Business Roundtable Report
1. Build Public support for making STEM education a national priority 1a. Launch a media campaign to help parents, students, employers, and communities to understand that STEM education is so important to individual success and national prosperity. 1b. Expand the State Scholars Initiative to encourage students to take rigorous academic courses in high school.
2. Motivate U.S. students and adults to enter STEM careers, particularly underrepresented groups. 2a. Create more scholarships and loan forgiveness programs, and build on existing ones. 2b. Increase the retention rate in STEM education 2c. Eliminate the security clearance backlog that discourages U.S. work in the security sector 2d. Establish prestigious fellowships for STEM graduates who teach in high poverty areas. 2e. Create opportunities for high achieving high school students in local magnet programs 2f. Adopt curricula that has rigorous content and real-world examples in engineering and science.
3.Upgrade K-12 math and science teaching to foster student achievement. 3a. Promote performance-based compensation for STEM high school teachers. 3b. Support professional development and other technical assistance 3c. Include government incentives for colleges to graduate more STEM majors 3d. Launch a “Math Next” initiative after the current “Reading First” initiative. 3e. Provide on-line STEM alternatives for schools that do not offer advanced math and science
4.Reform Visa and immigration policies to enable the United States to retain and attract the best and brightest in STEM professionals in the world market. 4a. Provide an expedited process for obtaining residence for these professional. 4b. Ensure a timely process for international STEM students to enroll in U.S. universities.
5. Boost and sustain funding for basic research in the physical sciences and engineering. 5a. Reverse declines in the federal share of R&D spending in this area.

The NAE Engineer 2020 Project

In 2004, the National Academy of Engineering (NAE) convened a blue-ribbon panel to establish a vision of what engineering would be like in the year 2020. This vision was articulated in a broadly accepted pamphlet[7] called the "The Engineer of 2020." The pamphlet focuses on future scenarios for engineers (such as climate change, nanotechnology, and biotechnology) and the training they will need to meet these future opportunities. The one common theme was that much change is needed, and much of that change was laid at the feet of engineering education. To that consequence, NAE commissioned a second group in 2005 to study the educational requirements to produce the envisioned engineer of 2020. This group produced a second NAE pamphlet[8] called "Educating the Engineer of 2020." This resulted in a set of 14 recommendations for engineering education, as listed in Table 4.

Table 4: Recommendations for Engineering Education from the "Engineer 2020" Project
1. Make the BS degree the "Pre-Professional Engineering" degree.
2. Make the MS degree the "Professional Engineering" degree with licensure.
3. Use outcomes-based accreditation to allow for innovation and experimentation in the engineering curriculum.
4. Teach the design process throughout the curriculum, starting in the first year.
5. Engineering deans should endorse faculty research in engineering education.
6. Develop new standards for engineering faculty qualifications, such as professional practice.
7. Teach students how to learn, and promote the value of life-long learning.
8. Introduce interdisciplinary activities at the undergraduate level.
9. Use case studies, both successes and failures, in engineering education.
10. Engineering schools should work with community colleges to ensure effective articulation.
11. Encourage domestic students to pursue the Ph.D. in engineering to improve the faculty pipeline.
12. Engineering schools should participate in a national effort to improve math, science, and engineering education at the K-12 level.
13. Participate in a national effort to promote public understanding of engineering and technology in our society.
14. Collect data from engineering programs on such factors as: student retention rates by gender and ethnicity; common reasons students leave engineering; percent who graduate on time in engineering, information on jobs graduates take; and how many go to graduate school.

ABET OUTCOMES

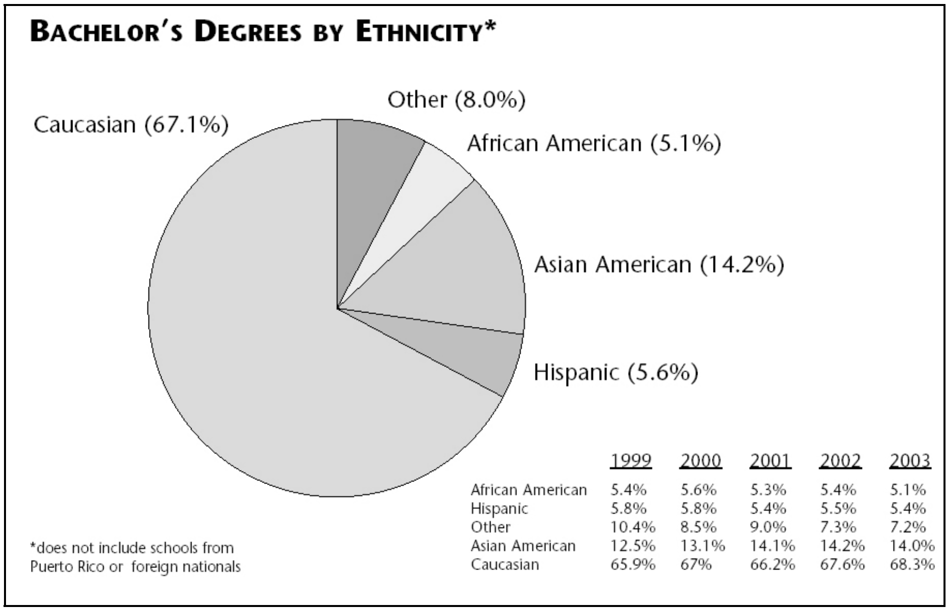
The past decade has seen much change in the way engineering programs are accredited in the United States. Much of this change has come in the form of the outcomes-based assessment and continuous improvement process requirements imposed by EC 2000 [ABET, 2000]. This new requirement forces engineering faculty to promote, measure, and evaluate their students' knowledge and abilities in key areas deemed necessary for modern engineering practice. These outcomes are listed in Table 5 and have been "affectionately" dubbed a-k.

Table 5: ABET Program Outcomes (a - k)
(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

While many engineering faculty malign a-k as just more bureaucratic workload, tracking ABET outcomes does offer a new opportunity for assessment and curriculum reform in engineering education, as suggested by Engineer 2020 recommendation number 3 (see Table 4). In addition, it seems that there is some merit in producing engineers that possess these a-k outcomes. One can not deny that science and engineering competencies, problem solving and design skills, computing and experimental skills, communication and team work, and knowledge of professional and contemporary issues, are all valuable attributes to have in a modern world. Indeed, the well-educated, learned citizen of the near future could very much be an engineer with solid EC 2000 skills. This leads to an interesting question: could engineering become the liberal arts degree for the 21st century?

ENGINEERING DEMOGRAPHICS

Much effort has been made in engineering to overcome the white male dominance of the profession in the United States. Although some improvement can be seen over the last half-century, it has not happened at an acceptable rate and seems to have stalled in the past decade. Both women and minorities are still significantly underrepresented in the engineering ranks, and the current student pipeline does not suggest much change is on the horizon, unless significant programs are implemented.



	1999	2000	2001	2002	2003
African American	5.4%	5.6%	5.3%	5.4%	5.1%
Hispanic	5.8%	5.8%	5.4%	5.5%	5.4%
Other	10.4%	8.5%	9.0%	7.3%	7.2%
Asian American	12.5%	13.1%	14.1%	14.2%	14.0%
Caucasian	65.9%	67%	66.2%	67.6%	68.3%

*does not include schools from Puerto Rico or foreign nationals

Figure 2. Bachelor's Degrees by Ethnicity in the U.S. (Source: ASEE)

Figures 2 and 3 show the current trends in bachelor's degrees in engineering[9] in the U.S. Currently, approximately 67.1 % of engineering degrees are awarded to Caucasians, 14.2% are Asian Americans, 5.6 percent are Hispanics, 5.1% are African American, and 8% reported other ethnicity. The sidebar on Figure 2, which shows the trends from 1999 to 2003, is discouraging because no rise is seen in increasing ethnic diversity in engineering. The data for gender diversity look no better. Overall, the number of female engineering graduates appears to have stalled at around 20%, and has not changed much in twenty years.

One interesting fact about the percentage of women in engineering is that it is not even across all major disciplines. For example, as shown in Figure 4, the percentage of women in traditional engineering fields like mechanical and electrical are below the 20% norm. On the other hand, the percentage of women in biomedical engineering is 45%, in environmental engineering is 40%, and in agricultural engineering is 37%. So it appears that women who are attracted to engineering tend to gravitate to majors that have a perceived image of "studying and protecting of human life."

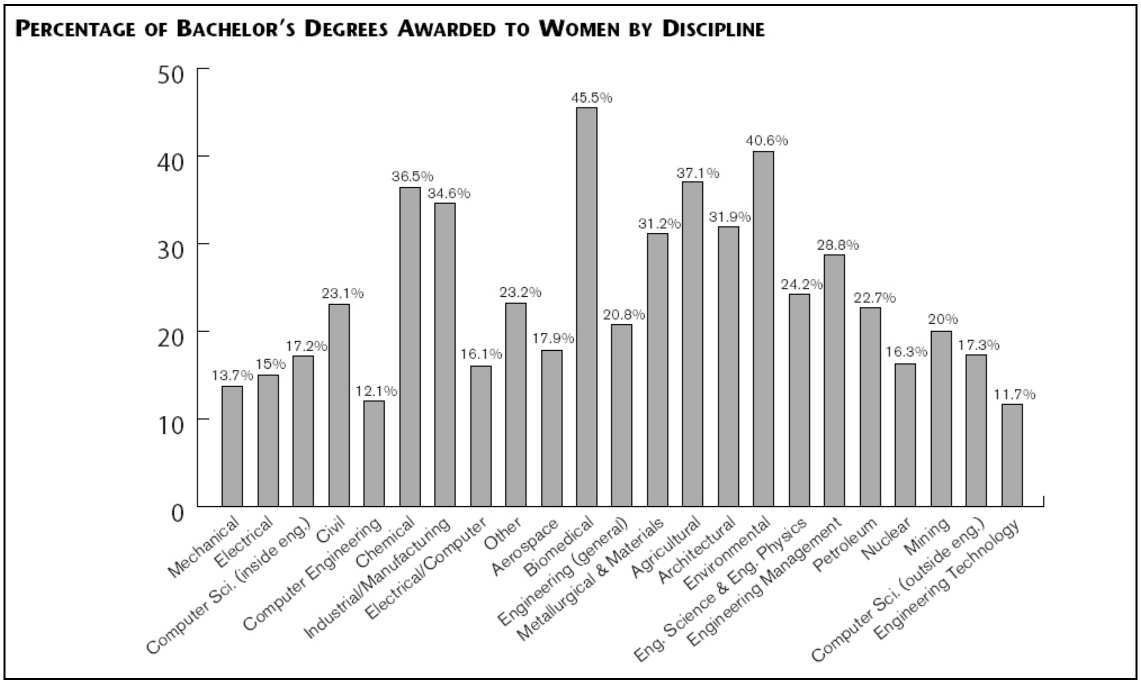


Figure 4. Bachelor's Degrees Awarded to Women by Discipline (Source: ASEE)

ASEE INITIATIVES

ASEE leaders and staff have been aware of these trends in engineering education and are acting to improve the condition. The basic mission of ASEE is to serve as the premier multidisciplinary society for individuals and organizations committed to advancing excellence in all aspects of engineering and engineering technology education. To this end, several current initiatives at ASEE are presented here.

The K-12 Initiative

In the past half-decade, ASEE has made significant progress in the K-12 education arena. A K-12 constituent committee was formed a few years ago, and in 2005 it received division status with over 400+ members. In an effort to promote engineering careers to middle and high school students, the ASEE publications department created the "Engineering: Go For It" magazine (Figure 5). The magazine has been widely accepted and over 600,000 copies have been distributed to date. An all-day K-12 workshop was developed and presented at the ASEE 2004 Salt Lake City and 2005 Portland annual conferences, and the near-term plan is to have this as a regular event at the annual conference. A new manager and department for outreach was created within the ASEE staff structure in 2005.

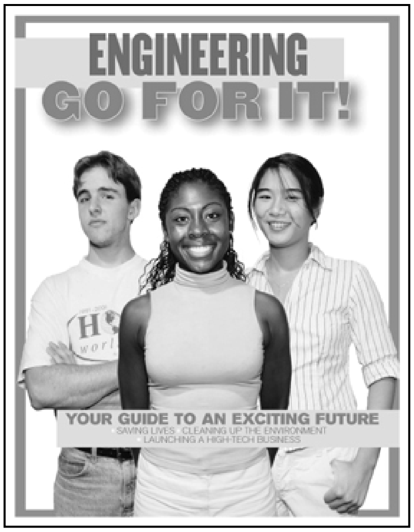


Figure 5. ASEE Go For It Magazine.

Copyright © 2006, American Society for Engineering Education

The Scholarship of Engineering Education

Recent events have accelerated the interest in engineering educational research. These include new ABET criteria and evaluation processes, new teaching and learning technologies in the classroom, NSF support of engineering education projects, and re-thinking of basic engineering learning paradigms. ASEE has maintained an active role in this area, including serving as PI in several grants. The ASEE Journal of Engineering Education (JEE) has been upgraded to be the premiere world journal for research in engineering education. The main plenary at the 2006 ASEE Annual Conference in Chicago features a Socratic dialog of eight panelists addressing the topic "Advancing Scholarship in Engineering Education: Launching a Year of Dialog." The ASEE section meetings in 2006-2007 could well serve as a broad dissemination mechanism for needed discussion on this topic by rank-and-file ASEE members.

ASEE International Activities

ASEE has started an annual Global Colloquium on Engineering Education (GCEE). Table 6 shows the world-wide hosting of these events projected through 2007. As part of this global partnership, ASEE has formed the International Federation for Engineering Education Societies (IFEES). The goal of IFEES is to provide a forum for communication, cooperation, and coordination of activities among the engineering education societies of the world. To facilitate this new international endeavor, ASEE created a new international activities department and manager within the ASEE staff structure in 2005.

Table 6. ASEE Global Colloquium on Engineering Education

Year	**Host Site**
2002	Berlin, Germany
2003	Nashville, Tennessee
2004	Beijing, China
2005	Sydney, Australia
2006	Rio de Janeiro, Brazil
2007	Istanbul, Turkey

Reaching the Media

In modern American society, no message can be delivered without significant effort to reach the public through the national media. ASEE has a strong publications department that has made meaningful effort to spread the value of engineering education to the general American public, including successful publication of an ASEE President's editorial in a major daily U.S. newspaper[10].

CONCLUSIONS

The world of engineering education has changed in the past quarter century. Figure 1 dramatically shows the decline in United States superiority in science and engineering education between 1975 and 2000. Many faculty believe that engineering education in America is at a crossroads and much change is needed to halt this world-wide decline. The key is to engage more public awareness and participation in engineering education, starting in K-12 and continuing through the college level, where significant engineering education reform is needed. ASEE originated in 1893 as the "Society for the Promotion of Engineering Education." That charge is as true toady as it was a century ago. We must, as a group, promote the value of engineering in America if we are to prosper economically and remain secure as a nation.

REFERENCES

1. Friedman, Thomas (2005): *The World Is Flat : A Brief History of the Twenty-first Century*, Farrar, Straus, and Giroux, New York, N.Y.

2. National Science Foundation (2004): NSF Science and Engineering Indicators 2004. http://www.nsf.gov/statistics/seind04/start.htm.

3. Murray, Charles (2005): America's High-Tech Quandary, *Design News*, Issue 18, December 5.

4. Augustine, Norman (2005): *Rising Above the Gathering Storm*, National Academies Press, Washington, D.C. (available at http://www.nap.edu/execsumm_pdf/11463.pdf)

5. Business Roundtable (2005): "Tapping America's Potential; The Education for Innovation Initiative," Business Roundtable, Washington, D.C.

6. Fogg, Neeta, Harrington, Paul, and Harrington, Thomas (2004): *College Majors Handbook with Real Career Paths and Payoffs: The Actual Jobs, Earnings, and Trends for Graduates of Sixty College Majors*. JIST Publishing, Indianapolis, Ind.

7. National Academy of Engineering (2004): *The Engineer of 2020*, The National Academies Press, Washington, D.C.

8. National Academy of Engineering (2005): *Educating the Engineer of 2020*, The National Academies Press, Washington, D.C.

9. Gibbons, Michael (2004): Profiles of Engineering and Engineering Technology Colleges, ASEE, Washington, D.C.

10. Barr, Ronald (2005): "U.S. Needs More Engineering Students," *Miami Herald*, August 11, 2005 editorial.

BIOGRAPHY

RONALD E. BARR

Dr. Ronald Barr is Professor of Mechanical Engineering at the University of Texas at Austin, where he has taught since 1978. Barr was the 1993 co-recipient of the ASEE Chester F. Carlson Award for innovation in engineering education. Barr is a Fellow of ASEE and serves as ASEE President from 2005-2006. He is a registered Professional Engineer (PE) in Texas.

Copyright © 2006, American Society for Engineering Education