A CASE FOR ENGINEERING EDUTAINMENT IN THE 21ST CENTURY

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Abstract *¾ The economic future of the United States depends upon our continued leadership in the development of high technology products and services. Development of such products requires a robust engineering workforce. Unfortunately, current economic, market, employment, demographic, and education trends suggest erosion of America's global engineering leadership. A definition of engineering edutainment is developed herein. Reasons why some educators are dismayed by the concept of edutainment are discussed. A call is made for engineering edutainment that spans almost all U.S. demographic groups from cradle to grave. This holistic approach is offered as a critical underpinning for the foundation of the engineering workforce of the next century. It is put forth that the holistic approach is best accomplished through alliances including engineering faculty, K-12 educators, and practitioners from industry. Finally, guidelines to avoid the pitfalls of edutainment are provided.*

Index Terms ¾ Instructional methodology, edutainment, economic impact of technology.

BACKGROUND

Edutainment is a subject of recent debate [1]. Advocates claim that it increases student attention, motivation and retention [2]-[3]. Others view edutainment as a means to develop social, linguistic and spatial skills - the whole student - in addition to the mathematical and logical skills [4] emphasized in traditional engineering education. But many educators balk at the term [1]. While institutions of higher education are often at the forefront of conception of such systems, they often lag behind in their implementation [5]. Why change methods for the 21st century when generations of engineers have been successfully educated using lectures and, less frequently, socratic or apprenticeship methods?

The idea of edutainment can be threatening for engineering faculty. The concept suggests yet another demand on faculty that are already pressed with growing teaching, research and service loads. This is a legitimate concern; it takes time to produce quality instruction [6]

It also implies risks to professors' dignity. A lapse into physical comedy in the middle of a thermodynamics lecture could cost the respect of the students. A formal definition of "engineering edutainment" may help to address this concern.

Engineering is variously defined [7] as:

1. the practical application of science and mathematics, as in the design and construction of machines, vehicles, structures, roads, and systems.
2. the action, work, or profession of an engineer.
3. skillful or artful contrivance or manipulation.

The first definition seems to be the best fit given the current context.

Edutainment is a contraction of the terms "education" and "entertainment." Parsing the term into its components we find the definition of education [ibid.] is:

1. the act or process of imparting or acquiring general knowledge and of developing the powers of reasoning and judgment.
2. the act or process of imparting or acquiring particular knowledge or skills, as for a profession.
3. a degree, level, or kind of schooling: a college education.
4. the result produced by instruction, training, or study.
5. the science or art of teaching; pedagogics.

The second definition is most suitable for engineering edutainment, though the fifth definition would also be adequate for the current purpose and has the added benefit of concision.

Entertainment is defined [ibid.] as:

1. the act of entertaining.
2. diversion; amusement.
3. something affording pleasure or amusement, esp. a performance.
4. hospitable provision for the needs and wants of guests.
5. a divertingly adventurous, comic, or picaresque novel.

The first definition provides little additional insight. The second, third and fifth definitions help illuminate some sources of faculty consternation with the concept of engineering edutainment. Professors strive for students to be engaged in thoughtful deliberation, not amused and diverted. "Performance" also implies a passive role for students rather than active engagement. Definition number four comes closest to being an acceptable component for a definition of engineering edutainment. However, the term "guests" begs for adaptation. Guest implies a visitor or customer who passively receives gifts or purchases. Anecdotal evidence suggests that some students favor this paradigm; a colleague often expresses the sentiment that students "think they're the customer when they're really the product." Rather, students must be active partners in their own education [8]. The alternative definition of entertainment, "hospitable provision for the needs of learners," is offered for consideration.

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Finally, these elements can be combined into a proposed working definition of engineering edutainment: "the art and science of hospitably teaching the practical applications of science and mathematics."

JUSTIFICATION

In order to appreciate why the United States needs engineering edutainment in the 21st century, it is necessary to recognize why it needs engineers. The U.S. has long been a debtor nation. As illustrated in Figure 1, high technology products represent a bright spot in U.S. foreign trade [9].

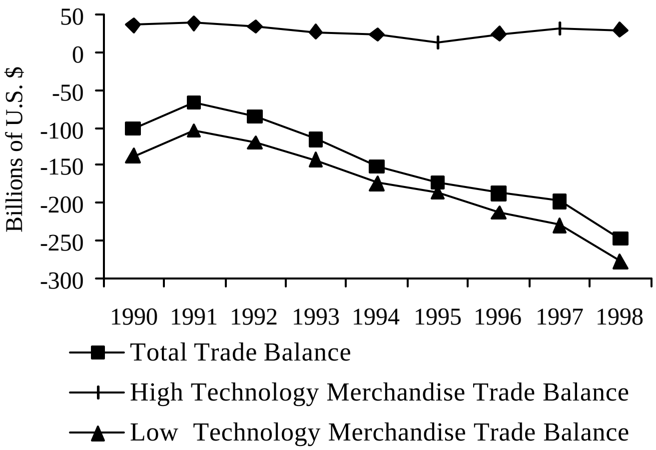

FIGURE. 1
U.S. MERCHANDISE TRADE BALANCE.

America's leadership position in high technology is constantly being challenged [ibid.]. The United States is a net exporter of drugs and medicines, but it lags behind both Germany and the UK in terms of global market share. Japan is a strong competitor in communications equipment. The aerospace industry has lost both domestic and global market share every year since 1990. Figure 2 shows the global export market shares for the dominant countries in the major high technology markets.

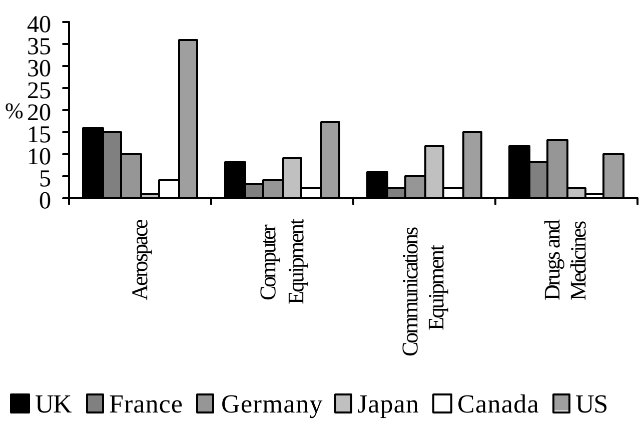

FIGURE. 2
EXPORT SHARE BY INDUSTRY FOR SELECTED G7 COUNTRIES - 1997.

The U.S. low technology trade deficit is approximately five times larger than the high technology trade surplus. American workers enjoy relatively high wages and living standards, but U.S. labor productivity growth has lagged the rest of the world for almost 40 years [ibid.]. These facts combine to make it increasingly unlikely that the U.S. will be competitive in the export of low technology merchandise. Therefore, to achieve a neutral trade balance in the next century, the U.S. must increase both its global market share and the total international market for high technology exports. According to the U.S. Census Bureau [10], the resident population of America has grown consistently for the last decade and will continue to throughout the coming century. This suggests that domestic demand for high technology products will increase and compete with opportunities for export while creating new import demands.

The United States needs a strong engineering education system to compete in increasingly competitive global high technology markets. According to the latest forecasts from the Bureau of Labor Statistics, U.S. employment opportunities in engineering are expected to grow 10-20% in the next decade, but the number of engineering degrees granted has remained fairly constant [11]. If current trends prevail, the demand for engineers may exceed the supply.

Except for computer science, the greatest population density of individuals with science and engineering degrees occurs between the ages of 40 and 49 [9]. The number of retirements will increase drastically in the next 10-15 years, especially among Ph.D. holders because of the steepness of their age profile [ibid.]. This trend has several implications. The aging population has resulted in explosive growth in demand for both adult education [12] and distance education [13]. Mass retirements in Ph.D. holders suggests that these demands will be harder to satisfy in the future. Finally, a constant rate of degrees granted combined with an increasing retirement rate does not bode well for satisfying America's 21st century demand for engineering talent.

Recent data [9] indicates that U.S. unemployment rates for engineers are well below two percent, regardless of engineering discipline or degree. Figure 3 illustrates unemployment rates by degree attainment for the 3 largest engineering disciplines and for engineers overall.

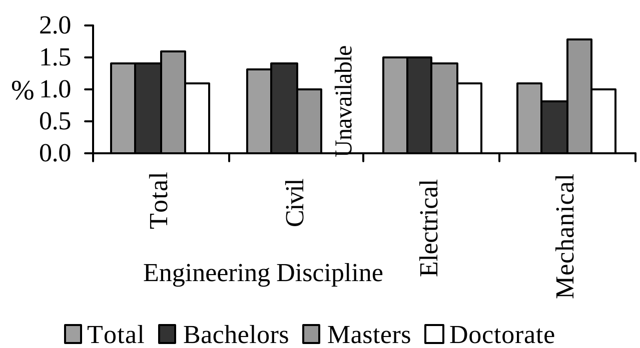

FIGURE. 3
UNEMPLOYMENT RATES OF SELECTED U.S. ENGINEERS - 1997.

Unemployment figures are another indicator of America's strong demand for engineers. Low unemployment levels also tend to increase inflationary pressures which, in turn, could harm the competitive position of U.S. high technology products in the global marketplace.

The United States has broad access to higher education. Thirty-two percent of 24-year olds in the U.S. have bachelor-level degrees; this is second in the developed world to the U.K [9]. In spite of high overall degree attainment levels, the U.S. lags behind all G7 nations except for Italy in the percentage of 24-year olds with first degrees in engineering [ibid.]. Figure 4 provides additional detail. The longer this engineering education lag exists, the more likely that errosion of American technology leadership will occur.

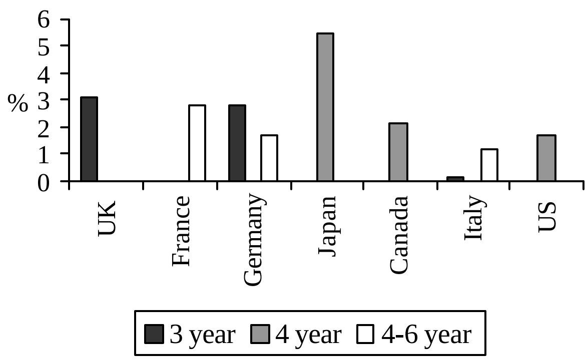

FIGURE. 4
PERCENT OF 24-YEAR OLD POPULATION WITH FIRST DEGREES IN ENGINEERING FOR G7 COUNTRIES - 1997 OR MOST RECENT YEAR.

The situation appears to improve somewhat with graduate education. The U.S. ranks 5th among the G7 with 23 engineering doctorates per million population (Figure 5). However, this quantity may be misleading; approximately 50% of the doctorates awarded in the U.S. are granted to foreign students and half of them, or 25% of all students obtaining doctorates in the U.S., leave the U.S. shortly after receiving their degrees [9].

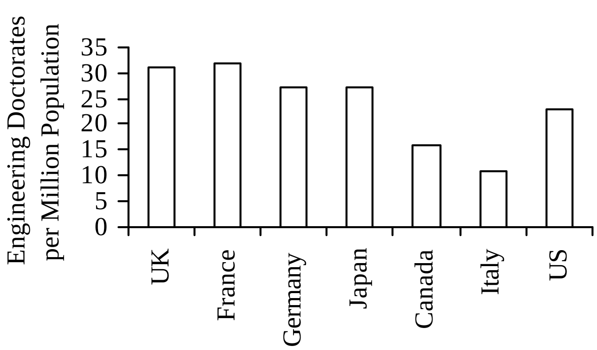

FIGURE. 5
ENGINEERING DOCTORATES PER MILLION POPULATION FOR G7 COUNTRIES - 1997.

Relatively low U.S. attainment of engineering doctorates follows logically from the modest percentage of baccalaureate degrees. Similarly, achievement in engineering at the bachelor's level follows from poor preparation in K-12 education. A relatively low level of mathematics and science proficiency is evident among first-year U.S. college students [9].

The Third International Mathematics and Science Study (TIMSS) was conducted in 1995 and gives a basis for international comparisons for both "all" and "advanced" students [14]. Steps were taken to ensure representative sampling in all participating countries. Ninety-five percent confidence intervals are used to assess whether statistically significant differences exist between the performance of U.S. students and students in other countries.

Comparisons show that US. student achievement in science and mathematics is above average in elementary school and average in middle school, but well below average at the end of secondary school [ibid.]. In the general science assessment which was administered during the spring semester to samples representative of all high school seniors, the U.S. score was significantly lower than 11 other nations, statistically comparable to 7 nations, and significantly better than only Cypress and South Africa among the 21 countries participating. In the general mathematics assessment of all high school seniors, the U.S. was statistically outperformed by 14 countries, comparable to 4, and again statistically superior to only Cypress and South Africa.

Sixteen countries participated in the TIMSS assessments of advanced mathematics and advanced physics students [ibid.]. U.S. high school seniors who participated in the advanced mathematics assessment had to either be currently enrolled in or have already completed a course with the word "calculus" in the title. The U.S. scored fifteenth among the sixteen participating countries and 11 nations exceeded the U.S. score with statistical significance. None of the participating nations scored significantly lower than the U.S.

U.S. high school seniors who participated in the advanced physics assessment had to either be currently enrolled in or have already completed Physics II or Advanced Physics. The U.S. scored lowest among all participating countries. The score was significantly lower than 14 participants and statistically similar to one participant.

Factors contributing to the relatively poor performance of the U.S. aren't entirely clear. Recent genome research casts doubt on a genetic or racially-based explanation for observed performance differences [15]. The U.S. is one of the most affluent TIMSS participants, expressed as gross national product (GNP) per capita [14]. Public spending on primary and secondary education as a percentage of GNP is similar in most TIMSS countries; this fact combined with U.S. affluence results in relatively high per capita public spending on primary and secondary education in the U.S. Despite this fact, U.S. performance, on average, resembled the economically less-affluent countries. Though this implies an inefficient system for primary and secondary education in the U.S., TIMSS did not measure private spending on primary and secondary education. This factor may compensate for lower levels of public spending.

Differences in curricula appear to be one source of the performance disparity; mathematics and science topics are, on the average, introduced later in the U.S. curriculum than in other TIMSS countries [ibid.]. For example, the material covered in the general mathematics assessment is introduced in seventh-grade in most TIMSS countries, but was most equivalent to the ninth-grade curriculum in the U.S. Also, the TIMSS average hours of homework per day for high school seniors was significantly higher than the U.S. average.

Numerous sociological factors undoubtably contribute to performance differences. In spite of its national affluence, U.S. students were by far the most likely to have outside jobs that required them to work on school days and they work a significantly higher number of hours per school day than all other TIMSS participants [ibid.]. As a result, U.S. students have less time for homework and are likely to have less energy to devote inside of school.

Also, there is strong correlation between personal safety and national performance on the assessments [ibid.]. Only students from South Africa were statistically more likely than U.S. students to have had something of theirs stolen at school or to have been threatened at school in the month immediately preceding the TIMSS assessments. It seems obvious that it is more difficult to attend to educational matters when one is concerned about the security of themselves and their belongings.

Finally, lack of interest and achievement in engineering among secondary school students is apparently a reflection of society at large. Based on a recent survey [9], only 44% of the U.S. general public expresses interest in science and technology; only twelve percent were self-described as attentive to science and technology. The term "attentive" was defined as a subject who simultaneously expressed three traits: interest in science and technology, a feeling of being well informed about science and technology, and frequently reading about current events relevant to science and technology. These results varied by level of educational attainment, ethnicity and gender (Figure 5). As a result of this general lack of public attention and interest, secondary school students may not be encouraged to pursue an engineering education by parents, role models and peers.

While organizations like the American Society for Engineering Education and the Institute for Electrical and Electronics Engineers should continue to pursue social, political, structural and curricular reforms to improve the engineering education system, individual faculty members must seek improved pedagogical techniques to help improve the condition of U.S. engineering education in the 21st century.

RECOMMENDATIONS

The focus of engineering education in the United States needs to broaden beyond university students to include the general public. Engineering edutainment should be considered as a framework to engage these diverse constituencies.

As it is traditionally defined, edutainment is an industry-driven activity practiced by the likes of Disney and Apple Computer [16]. The proposed definition of edutainment, hospitable teaching, is intended to suggest a "big tent" of pedagogical and public relations techniques, the contents of which are systemically driven by intellectual institutions rather than by fickle market forces. This big tent would include, but would certainly not be limited to, computer-enhanced instruction, collaborative learning, distance education, and accommodation of individual learning styles. These and other techniques need rigorous definition, evaluation and, if justified, systemic implementation.

Engineering faculty can take advantage of the benefits of edutainment while avoiding its hazards by keeping a few guidelines in mind.

First, substantial content and learning outcomes must be conceived before edutainment is utilized [4]. Edutainment can't make a relatively trivial topic into something pertinent.

Second, the approach to that substantial content must respect basic intellectual norms [ibid.]. For example, a group exercise that utilizes a computer simulation of a nuclear reactor may encourage skills such as inquisitiveness and team-building, but blind trial-and-error experimentation without first providing a foundation of relevant information fails to take full advantage of the opportunity to reinforce logic and reasoning skills. Exploration must be directed by subject matter knowledge.

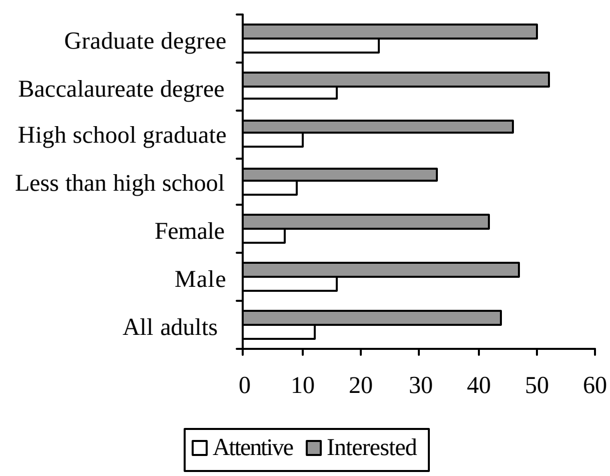

FIGURE. 5
U.S. PUBLIC INTEREST IN AND ATTENTIVENESS TO SCIENCE AND TECHNOLOGY- 1999.

Conversely, the curriculum must leave room for interactive exploration by students [8]. The notion that edutainment is primarily a series of performances that are passively absorbed by students must be avoided.

Fourth, don't edutain all of the time. Students, especially those in postsecondary situations, must learn that it is necessary to attentively complete tasks whether they are "fun" or not [5].

Fifth, faculty must avoid the "low road" aspects of entertainment such as sarcasm and slapstick [2]. In all but the most limited contexts, these affectations aren't relevant to the course content. They can also undermine respect for the subject, the professor and for fellow students.

Next, borrow a page from industry's book and forge a supply chain alliance. Specifically, form edutainment partnerships with industry representatives and with K-12 math and science teachers. This is certainly not a "quick fix", but rather a long-term investment to improve the "raw materials" from which we will jointly build the future of engineering. K-12 teachers can bring advanced pedagogical knowledge to complement professors' advanced scientific scholarship along with industry's resources and "real world" grounding. All parties can help positively expose engineering to constituents from cradle to grave.

Finally, engineering faculty should play to our strengths. As Clarke's Third Law [17] states, "Any sufficiently advanced technology is indistinguishable from magic." Magicians are entertainers and the best magicians inspire curiosity in their audiences as to how the trick works. Examples of the "science as magic" approach to edutainment include Honeywell's INVEST Program (Industry Volunteers Encouraging Science and Technology) and the University of Minnesota's Chemistry Outreach Program. The author has first-hand knowledge of how these programs inspire interest in engineering, science and technology for the general public and, especially, K-12 students. The U.S. is counting on these students to bootstrap the future of engineering in the 21st century.

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