

Integrating Engineering into the Secondary School Curriculum -- A New Approach

Thomas G. Johnson

**Computer Engineering and Computer Science Department
California State University, Long Beach**

Abstract

The realization that a secondary school education often provides very little exposure to what an engineer actually does at work has led the Computer Engineering and Computer Science Department of the California State University, Long Beach to approach this problem in a novel way. Specifically, we have designed a new single subject degree option, a *BS in Engineering, Option in Technology and Engineering Education*, which prepares middle school and high school teachers to integrate technology into the current California curriculum of mathematics and science. The goal is to develop a credentialed teacher who understands the engineering discipline and its reliance on and development of technology and can convey the utility and rewards of a career choice in the field of engineering to the college-bound student.

Introduction

Many K-12 educators do not know what engineers do and probably have not met an engineer. So far there has been a sort of band-aid approach to the problem of role models for K-12 students. Outreach programs exist including those from public and private organizations like ASEE, MESA, IEEE, NASA, and Boeing. Engineering Information Foundation and Project Lead The Way are involved in activities to promote engineering in the pre-college education system. However, in spite of all of these efforts, enrollments in engineering programs are still falling. With the allotment of H-1b visas rising from 65,00 in 1998 to 195,000 in 2001, there are concerns about the lack of interest and preparation of American students especially in the engineering fields.

This paper discusses another approach to informing K-12 students about engineering as a creative and fulfilling career choice. Presently, three factors suggest a means of encouraging California's students to be engineers:

- The California Commission on Teacher Credentialing has rewritten the subject matter requirements for the Industrial and Technology Education single-subject teaching credential placing an emphasis on technology.
- The current California K-12 curriculum is already very full and well defined.

- The International Technology Education Association and its Technology for All Americans Project have developed a set of criteria for technology education in its Standards for Technological Literacy: Content for the Study of Technology developed with funding from the National Science Foundation under Grant No. ESI-9626809 and the National Aeronautics and Space Administration under Grant No. NCC5-172.

Taking advantage of the concern for technology education expressed above and the need for credentialed educators in the K-12 programs for teaching science, math and computer programming, it is natural to consider a clear credential program in Industrial and Technology Education to help meet the shortfall of math and science teachers existing today. It has been proposed that within the Bachelor of Science in Engineering, an option in Technology and Engineering Education be established that will provide fully credentialed educators who want to teach technology, programming, mathematics, physics, electronics, drafting and other engineering related courses at the secondary school level in California. Currently there are many opportunities for such credentialed teachers within schools that have or want to have Advanced Placement Computer Science courses for example, and within technological and engineering academies that exist in many high schools, not to mention the ever expanding need for qualified math and physics teachers statewide.

Rationale

The CSU system is responsible for 60% of the state's teachers, and a huge percentage of those entering the teaching profession are women. It is well known that women are under-represented in the areas of engineering and technology, even though most of the new entrants into the nation's workforce are women according to the Engineering Information Foundation¹. In order to stay competitive in the global economy, a way must be found to ensure more women are made competent for leadership roles in the technology fields. At present, there are few role models during the early years of school to help women overcome negative stereotypes and perceptions about engineering, which hinders many well-qualified women from pursuing a career in the field, and such an argument can be made for other minorities as well. Role models must come early in the educational process to have a chance at making the difference everyone hopes will come.

Although there are computers and internet connectivity at most every school, it is reported that only 33% of teachers feel "well" or "very well" prepared to use a computer technology for instruction, and even less feel prepared to teach programming or technology or engineering related subjects². A sobering statistic was reported in Education Week in 1997: in the US, the average of teachers who had at least 9 hours of training in education technology was 15%. California was reported at the average³.

In the Digital High School Education Technology Grant Act of 1997 (AB 64) the California Legislature stated that⁴:

- 1) Computer knowledge and skills are essential for individual success in school and career and for the continued economic prosperity of the State of California.
- 2) All pupils in California must be "computer literate" before they complete high school.

3) Traditional learning is enhanced by appropriate technology.

California has increased the level of computer proficiency required for a teaching credential. Standard 20.5 of the California Commission on Teacher Credentialing requires that teachers demonstrate “Level 1” proficiencies before receiving a Preliminary Credential, and demonstrate “Level 2” proficiencies to receive a Professional Credential⁵. Even so, teacher preparation does not include any requirements in either computer science or engineering. Educational technology courses are being proposed to fulfill these requirements, but a credential awarded by completing the program proposed here will certainly provide schools an adequate pool of people that have more than minimal skills in these areas.

According to the Department of Education⁶, bachelor’s degrees in engineering have fallen from 7.7 percent of all degrees in 1986 to only 5.1 percent in 1998. Only 3.1 percent of Afro-American college students and 4.9 percent of Hispanic college students choose engineering as a major. Worse yet, only 1.7 percent of all women in bachelor degree programs complete an engineering degree. Compare this with several other countries: Mexico at 8.2 percent, South Korea at 7 percent and Japan at 4.3 percent. There must be an increase in the pool of women and minorities majoring in engineering to increase the number of engineers. The lack of home-grown engineers is reflected in the number of H-1b visas rising from 65,000 in 1998 to 195,000 in 2001, and Congressman Vernon Ehlers, Chair of the House Science Committee’s Subcommittee on Environment, Technology and Standards, has expressed concern about the American economy becoming increasingly reliant on imported high-tech workers.

It is significant to note that the percentage of women earning bachelor degrees in computer science has decreased from 37 percent to 15-20 percent today. Also alarming is that the percent of women in engineering is less than 10 percent. Compare this to the medical and legal professions where 30 percent of doctors and 50 percent of lawyers are women. Of interest is to note the male-to-female earnings ratio for various professions as taken from the Bureau of Labor Statistics for the year 2000 wherein a level of 100 is parity⁷:

Health Professionals	141
Attorneys	136
Faculty	130
Scientists	128
Engineers	114

From this data we see that engineering exhibits near parity. In so far as parity reflects advancement through managerial levels, these figures highlight the potential opportunities for women in engineering that are not available in other professions.

In April 2000, the International Technology Education Association published “Standards for Technological Literacy: Content for the Study of Technology.” The list of the standards for technology literacy are⁸:

1. Scope of Technology
2. Core concepts of technology

3. Technological relationships
4. Technological effects on society
5. Technological effect on the environment
6. Role of society in technology
7. Evaluation and history of technology
8. Attributes of design
9. Engineering design
10. Methods to solve design problems
11. Ability to apply design process
12. Ability to use and maintain products and systems
13. Ability to assess impacts of products and systems
14. Medical technologies
15. Agricultural and related bio-technologies
16. Energy and power technologies
17. Information and communication technologies
18. Transportation technologies
19. Manufacturing technologies
20. Construction technologies

The California Commission on Teacher Credentialing (CCTC) Industrial and Technology Education Standards⁹ were revised to include most of these standards. One of the goals of the program outlined here is to ingrain teaching candidates with these standards with the hope they will pass them on to their students.

UC Standards

The intention of the new BS in Engineering option is to integrate technology into several of the University of California's a-g subjects that are required of high school graduates who wish to apply for acceptance into a UC school. These standards are promoted by Senate Bill 1731¹⁰ which in effect will make the UC a-g curriculum be the standard in all high schools by 2008. The difficulty that arises is getting potential CTE programs an "a-g" equivalency. To date, UC has largely not provided such certification according to the Industrial Technology Education Association. Instead, the program presented here is intended to integrate technology into several UC a-g subjects while trying to obtain the necessary a-g certifications for CTE courses. By doing this, college-bound students will be made aware of the role of engineers, the tools used by engineers (math, physics, programming, etc) and the impact engineers have on society through the established high school curricula. Additionally they will also be informed of the unintended consequences of technology on individuals, society and the environment. It is a challenge to work within the UC a-g constraints and still meet the technology literacy standards, but the proposed curriculum prepares teachers to do this. Currently at Long Beach Poly High school, a course was developed called "Introduction to Engineering" which did receive UC a-g equivalency, but another logic design course "Digital Logic Design" did not. In both of these cases, high school students are exposed to the challenges offered by a career in engineering. If there can be produced enough qualified teachers who have a strong background in technology and engineering, then we may see an upswing in engineering school enrollments as they teach students programming,

physics, math and other related subjects and include the engineer's role in technological progress. If successful, there should also be a widening scope of courses that will be given the UC a-g stamp of approval.

Technology education vs education technology

Though the College of Education on our campus is currently proposing a master's degree in Educational Technology, this does not address the need for teachers who can teach high-tech subjects in the classroom. There is a very important distinction between Educational Technology and Technology Education. The ITE Handbook makes the distinction that Industrial and Technology Education pertains to the content of learning whereas Instructional or Educational Technology focuses on the delivery of instruction. Instructional technology, as defined in A Report to the President and Congress of the United States by the Commission on Instructional Technology, is "a systematic way of designing, carrying out, and evaluating the total process of learning and teaching in terms of specific objectives, based on research in human learning and communication, and employing a combination of human and non-human resources to bring about effective instruction." The two areas are brought together because instructional technology is used in the delivery of Industrial and Technology Education, and components of it are among the many technologies that are included within ITE. The ITE Handbook¹¹ points out that learning to use computers and other technologies in the education process within ITE should be part of the subject matter teacher preparation program, and that "Instructional or Educational Technology is not Industrial and Technology Education."

Implementation

The proposed program uses existing resources found in the Computer Engineering and Computer Science (CECS) Department and other College of Engineering (COE) departments. This allows access to fully equipped laboratory facilities, support staff, and many highly trained faculty to teach courses in this option. There are among the faculty and full-time lecturers several credentialed secondary school teachers. By design, all but one of the ENGR courses are presently listed in the catalog and are taught by experienced faculty.

The Technology and Engineering Education option should be viewed as a complement to the existing Mathematics and Science Education options offered at most of the CSU campuses. But in the proposed option, the degree candidates are provided with much more modern technology skills essential for today's teachers. The program is unique in that it is offered within the College of Engineering, which with its CECS Department, emphasizes and includes the most up-to-date technologies in its curriculum.

Proposed Option

The proposed option is intended to be implemented as early as Fall 2003, fast-track approval permitting, or else in the Fall 2004. The course content for the proposed Bachelor of Science in Engineering, Option in Technology and Engineering Education (120 units) is for students preparing to teach technology/engineering courses, programming, physics, and/or introductory

mathematics at the secondary school level. Thirty units of post-baccalaureate coursework are also required for the Clear Single Subject Teaching Credential in Technology and Engineering. The course descriptions of the classes listed can be found in the CSULB Catalog 2002-2003¹². The requirements are (excluding the 51 units of General Education required by the University) as follows:

Lower Division: Physics 100A,B; Math 122,222; CECS 101, 110, 174, 200, 261, 274;
EE 210/210L; ENGR 200E; ET 250, 250L; ME 172, 272.

Upper Division: Math 310; ENGR 302I, 310, 340, 370I, 375I, 381, 391, 392;
CECS 300E, 310E, 401E.

Bibliography

1. Engineering Information Foundation RFP: Women in Engineering. Projects Directed by Engineering Educators.
Website: <http://www.eifgrants.org/info/progareas.html>
2. "Teacher Use of Computers and Internet in Public Schools," Cassandra Rowan, Education Statistics Quarterly, Elementary and Secondary Education, April 24, 2000 Website: <http://nces.ed.gov/pubs2000/quarterly/summer/3elem/q3-2.html>
3. "Training Called Key to Enhancing Use of Computers, Poll Finds", Andrew Trotter Education Week, April 16, 1997.
4. AB 64 Education technology. Bill Number: AB 64 Chaptered 08/19/97, California Department of Education.
Website: <http://www.cde.ca.gov/digitalhigh/AB64.htm>
5. California Commission on Teacher Credentialing.
Website: <http://www.ctc.ca.gov/profserv/progstan.html>
6. U. S. Department of Education Data.
Website: <http://www.ed.gov/index.jsp>
7. US Bureau of Labor Survey (2000).
8. "Standards for Technological Literacy: Content for the Study of Technology", International Technology Education Association, April 2000.
9. CCTC Industrial and Technology Education Standards, California Commission on Teacher Credentialing, 1999.
10. California State Legislature Senate Bill SB1731, February 21, 2002
Website for text of bill: <http://tcla.gseis.ucla.edu/rights/features/4/pdf/sb1731.pdf>
11. The ITE Handbook.
Website: http://www.ctc.ca.gov/profserv/programstandards/ite_handbook.pdf
12. The University Catalog 2002-2003, California State University, Long Beach, 2002.