A New Engineering Degree Program for Secondary School Teachers

Thomas G. Johnson

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

Abstract

In April 2000, the International Technology Education Association and its Technology for All Americans Project published Standards for Technological Literacy[1]. These standards have become a major focus in the revision of primary and secondary school curricula across the nation. A renewed emphasis is being placed on teachers to be competent in those areas addressed by the authors. After examining the high school curriculum currently in place, there has been a realization that a secondary school education as now constituted provides very little exposure to the skills and general problem solving techniques that is emphasized in the technology standards. Interestingly, the identified skills are much like the ones that an engineer develops in completing an engineering degree. The problem we face in California is that the State mandates the primary and secondary school curricula[2], and getting any changes made to the comprehensive and well-established program is a Herculean task, one that is exceedingly difficult and time consuming. As an alternative approach, we have developed an engineering degree option, viz. BS in Engineering Technology, Option in Technology and Engineering Education, which has as its purpose the introduction of technology in a comprehensive and understandable manner in the California school curriculum that is already in place. Specifically, we have designed a new single-subject degree option that prepares future middle school and high school teachers to integrate the technology standards into the mathematics and science courses of the California secondary school curriculum. The goal is two-fold: first developing competent and technology literate teachers, and second, by their efforts in the classroom, increasing interest in engineering and encouraging more students to enter the engineering profession. Currently this program is in the process of being evaluated for approval by the State of California. In this paper a detailed description of the program is presented, and some aspects of its development are discussed.

Introduction

The lack of technological literate teachers, as differentiated from computer literate or multi-media literate teachers, in the public school system today is partially responsible for the low interest levels and indistinct knowledge about engineering and information technology career opportunities open to many a bright and eager student. Since public school teachers play a significant role in shaping the interests, preparation, and subsequent career choice of high school graduates, it is important to maintain a solid core of well-educated and able teachers that can motivate and prepare sufficient numbers of students to become the high-tech personnel needed to

Copyright © 2004, American Society for Engineering Education

fill the country's employment demands in the future. That we do not produce enough skilled workers today to meet the current demand is witnessed by the import of high-tech workers from abroad and/or the export of high-tech jobs overseas. This concern is voiced by Congressman Vernon Ehlers, chair of the House Science Committee's Subcommittee on Environment Technology, and Standards. A glaring indication of this troubling trend is the observation of the allotment of H-1b visas having risen from 65,000 in 1998 to 195,000 in 2001. In view of this disturbing trend, American students must be made aware of the importance of secondary school preparation in determining their career options in high-tech fields. It is hardly revelatory that the K-12 teachers can be a major factor in how students perceive and receive awareness of the technology that surrounds them and how they can participate in its development and implementation.

In a society that values diversity, it is troubling to note that the percentage of women earning bachelor's degrees in computer science is down from 37 percent in 1984 to only 15-20 percent today. Worse yet is the fact the percentage of women in engineering is less than 10 percent. These trends are seen with respect to other minorities also[3]. When K-12 students find themselves in a classroom with a teacher who does not understand what constitutes technology or its impact on society, or know what an engineer or computer scientist does, their attitudes and impressions of a career in technology can easily be ill-formed, and that "first" impression can last far into the future. All too often the overall impression left with the student is negative – either engineering is too hard or too mysterious, or stereotypically only for nerds or misfits. By providing a talented pool of technologically literate teachers for the public school system, we hope that this unfortunate state of affairs can be reversed. In place of a very negative image, we hope that engineering will be presented as a welcoming, lively, and rewarding career.

Goals

The proposed degree has several objectives. It provides a strong understanding of what technology is and how mathematics and science relate to technology and technological fields of study. Identification of what technology processes and tools are, of how technologies are created, and how technology both shapes and is shaped by society are primary goals of the subject matter of the degree. In addition, the program provides the future teacher with engaging and relevant projects to use in the teaching of technology and/or related courses. The youth of today are bombarded with all sorts of high-tech gismos and gadgets, but they know little about how the devices were conceived, developed, and manufactured, or the skills required by the people to make them a reality. The degree program presented will prepare capable, enthusiastic, and knowledgeable teachers of technology who will be able to engage young learners in the exploration of the many areas of technology.

The degree program incorporates Information and Technology Education intended to bridge other disciplines offered to California public school students. This degree will require a supplementary authorization in computer concepts and applications (with an emphasis on preparation to teach Advanced Placement programming), and another supplementary authorization in introductory mathematics, introductory science or physics. The multi-disciplinary nature of the degree is intended to span various disciplines in the California public schools. Complicating matters somewhat is the federal legislation known as No Child Left

Copyright © 2004, American Society for Engineering Education

Behind (NCLB) which resulted in a cascade of legislation at the state level that affects teacher credentialing. NCLB mandates that all K-12 classrooms must be staffed with "highly qualified" teachers by January 2006. The State Board of Education in 2003 declared that such qualification would be achieved by meeting any of the following:

- Passing score on the appropriate CSET for the subject area
- Completion of a subject matter program or major approved by the California Commission on Teacher Credentialing (CCTC)
- Earned a bachelor's degree or graduate degree in the subject area taught
- Completed coursework equivalent to an undergraduate major in the subject area taught

However the CCTC said that the last two are not sufficient for subject matter competency for a credential in that area. This example is presented to show how difficult and complex the credentialing process has become with both state and federal policy and legislation in flux. In light of these developments, our degree program will not provide a supplementary teaching credential in mathematics or the physical sciences. However, the prospective teacher can still complete any additional classes needed to pass the CSET for subject matter competency to be qualified for such a credential[4].

Desired Outcomes

The central outcome of the degree is to provide ITE subject matter graduates with the ability to provide California's K-12 students with an education that includes technology literacy. The ITE subject matter graduates will have:

1. An understanding of how contemporary issues shape, and are shaped, by technology.
2. An ability to teach effectively using relevant projects and technology.
3. An ability to communicate effectively in oral, written, graphical, and multi-media forms.
4. An ability to identify, use and design electronic curriculum that meets state education standards and national technology literacy standards.
5. Knowledge of the Standards for Technological Literacy.
6. An understanding of technology as the products of technology design – both hardware and software.
7. An understanding of the relationships between science, math, and technology – specifically in the areas of engineering and computer science (part of information technology).
8. The ability to pass this knowledge on to California public school students.

The published CCTC ITE Standards[5] reflects an understanding of a more modern and relevant course of study for the ITE subject matter credential. Recognizing this change, it is important for universities to provide the new credential for our teacher candidates. It is very important that the College of Engineering take up the challenge of engaging in the essential process of teacher education, encouraging industry in offering scholarships and internships for candidates in this program, and beginning an active outreach program to recruit future teachers who will not only understand technology but also be enthusiastic about teaching it.

Copyright © 2004, American Society for Engineering Education

Program Design

This ITE subject matter program is designed as a practice-oriented program that develops well-trained teaching professionals. The intent is to place teachers into the local school districts who are above average in technology literacy. This literacy will not be limited only to the use of technology, but more importantly, it will also include literacy about the technology process used to produce high-tech products and the impact they have on society. In support of this goal, the university faculty is needed to provide experience with hands-on learning, problem solving, critical thinking, ethics, curriculum design and use of modern technology tools within a broad spectrum of technology areas. This breadth will allow the graduates of this program to clearly explain to their future students the relationships among the many technology careers and the related disciplines that have to be mastered.

The *Standards for Technological Literacy: Content for the Study of Technology* (*http://www.iteawww.org/TAA/PDF/Execsum.pdf*) developed through funding from both the National Science Foundation under Grant No. ESI-9626809 and the National Aeronautics and Space Administration under Grant No. NCC5-172, and the CCTC ITE Standards serve as guides for the content and design of this program. In the design of this program it was especially important that the courses provide the teacher candidates with a good background of how to engage different learners and how to assess learning outcomes. This can be achieved by engaging faculty in the College of Engineering (COE) who presumably are all very involved in meaningful assessment methods and scoring rubrics.

Basic Description of Program

Our program of subject matter preparation for the Single Subject Teaching Credential in Industrial and Technology Education consists of 48 semester units of course work in Industrial and Technology Education and closely related subjects. In addition to 36 semester units in the breadth courses, our program has one concentration area of communications consisting of 12 semester units. The proposed degree program addresses seventeen standards of program quality and excellence required for the State Board of Education review. It is broken into two parts:

I. Curriculum and Content of the Program
1. Program Philosophy and Purpose
2. Breadth of Study in Industrial and Technology Education
3. Depth of Study in a Concentration Area
4. Diversity and Equity in the Program
5. Computer Literacy and Educational/Instructional Technology
6. Industrial and Technology Education as a Profession
7. Career Opportunities and Preparation
8. Technological Literacy and Capability
9. Problem Solving Skills
10. Design and Systems
11. Technology and Society
12. Safety and Facilities Management
13. Field Experience

Copyright © 2004, American Society for Engineering Education

14. Coordination of the Program

II. Essential Features of Program Quality
15. Student Advisement and Support
16. Assessment of Subject Matter Competence
17. Program Review and Development

For each standard enumerated above, a specific matrix was developed to show how the various courses in the program meet the State Board of Education criteria for adoption of a new teaching credential proposal. This process consumes much space, and only an example for Standard 2 is shown below.

Our breadth courses address Standard 2 by developing foundations in communication; production; power, energy and transportation; and technology. The table below outlines in which course/s the required areas are covered. Following the table is a catalog description listing of all breadth courses that address Standard 2.

Required foundation areas.
a.) Communications
b.) Production
c.) Power, energy and transportation
d.) Technology (the act of making or crafting)

Table 1. Required breadth courses

Courses (in alphabetical and numerical order)	Semester Units	Area a	Area b	Area c	Area d
CECS101 The Digital Information Age	3	x			
CECS110 Intro to the Internet	3	x			
CECS200 Introduction to Web Design	3	x			x
CECS401E Prog . Robots - for Teachers & Parents	3			x	x
CECS410E Computers and Networks	3	x	x		x
ENGR302I International Devs in Renewable Energy	3	x	x	x	x
ENGR340 Guitar Electronics	3			x	
ENGR370I Astronautics and Space	3	x		x	x
ENGR375I Total Quality and Continuous improvement	3	x	x		
ENGR391 Engineering and Civilization	3	x			
MAE 101 Introduction to Aerospace Engineering	1		x		
MAE172 Engineering Design Graphics	3	x	x	x	x
MAE272 Introduction to Manufacturing Processes	2	x	x		x

Total of 36 semester units. 75% of subject matter program

Breadth Course Descriptions[6]

Computer Engineering & Computer Science (CECS) Courses

Copyright © 2004, American Society for Engineering Education

CECS101. The Digital Information Age (3)
Prerequisite: Category B2 General Education course. An introduction to commonplace digital information systems for non-majors. Information sources. Digital logic. Computer hardware and software. The Internet and the World Wide Web. (Lecture 3 hours.) Traditional grading only.

CECS110. Introduction to the Internet (3)
Prerequisite: Some computer experience. Provides a general overview of computer systems, networking, and the Internet. World-Wide Web, email, telnet, ftp, newsgroups, finding information on the Internet, and basic Web page creation. Considers legal, ethical, privacy and security issues on the Internet. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

CECS200. Introduction to Web Design (3)
Prerequisite: Some computer experience. Introductory Web page design using modern tools. Development of Web pages from layout to posting on the Internet. Web security and ethics. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

CECS401E. Programming Robots – for Teachers and Parents (3)
Prerequisite: Some programming experience. Learn how to inspire interest in engineering and computer science among children ages 9 through 16. Using robotic kits, gain hands-on experience in problem solving and computer programming while constructing and programming unique robot inventions. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

CECS410E. Computers and Networks (3)
Prerequisite: Some computer experience. Gain practical, hands-on experience in installing hardware and software on a PC. Learn what a computer network is and how it is similar to the telephone network. Learn the parts that make up a computer and a network. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

Engineering (ENGR) Courses

ENGR302I. International Developments in Renewable Energy and Cultural/Environmental Impacts (3)
Prerequisites: Completion of the G.E. Foundation, one or more Explorations courses, and upper-division standing. Renewable energy sources, available world resources, market, trends, and technology. Energy conservation and practical alternatives, social, cultural and economic impacts, environmental aspects of power generation, air pollution, depletion of ozone layer and greenhouse effect. (Lecture-problems 3 hours). Traditional grading only.

ENGR340. Guitar Electronics: Engineering Sound (3)
Prerequisites: Upper division standing, completion of Foundation curriculum, one course from G.E. category Blb. (Not open to students with credit in EE 333). Historical review of electro-magnetic principles and their application to the reproduction, modification, and creation of sound. The electric guitar, its amplifiers, and special effects devices (analog and digital) will be used to gain practical experience. Electrical safety, physiology and physics of the ear. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

ENGR370I. Astronautics and Space (3)
Prerequisites: Completion of the G.E. Foundation, one or more Explorations courses, and upper-division standing. This course combines the disciplines of space engineering with economics, human physiology, satellite meteorology, earth resources and environmental science, astronautics and space exploration. Emphasis on oral and written communications, numeracy and use of computers. Extensive use of computer animation, videographics and the Internet. (Lecture–problems 3 hours.) Traditional grading only.

ENGR375I. Total Quality and Continuous Improvement (3)
Prerequisites: Completion of the G.E. Foundation, one or more Explorations courses, and upper-division standing. The course examines the global competitiveness and the use of Total Quality approach to achieve Continuous Improvement. The topics include the following: History of quality movement, Quality gurus and Deming's philosophy on TQM, Strategic planning, Customer satisfaction, TQM tools, Effective visual representation of data, Worker empowerment and teamwork, Supply chain management, Statistical tools for controlling quality, ISO 9000 and its role in quality improvement, Malcolm Baldrige National Quality Award, Deming's Prize, Industrial practice and Case studies. The course fosters teamwork with Team project reports and oral presentations. (Lecture-problems 3 hours). Traditional grading only.

ENGR391. Engineering and Civilization (3)
Prerequisites: ENGL 100 and a Critical Thinking course (A3 category of GE) or consent of instructor. Study of the interaction between human beings, the environment, resources, engineering and science, including the impact of engineering on society. Readings and lectures providing perspective and insight into current problems at the interfaces between engineering and other disciplines, especially anthropology, art, ecology, economics, philosophy, psychology, science and the social sciences. (Lecture-Problems: 3 hours.)

Mechanical & Aerospace Engineering (MAE) Courses

Copyright © 2004, American Society for Engineering Education

MAE 101. Introduction to Aerospace Engineering (1)
Prerequisite: Consent of the instructor. This course is designed to introduce the students to the various aspects of aerospace engineering through a case history study of an actual aerospace vehicle product development and production program. This broad review highlights the roles of the various types of engineering specialists involved in the total program, and will enable students to define their areas of specialization in their junior and senior years.

MAE172. Engineering Design Graphics (3)
Graphics concepts and visualization. Graphic expressions using CAD software, emphasis on industrial practice involving part and assembly drawings for actual products, standards, tolerances, surface finishes, and other attributes on drawings, production drawings, projects involving complete design of systems and sub-systems. (Lecture-problems 2 hrs, design laboratory 3 hrs.) Traditional grading only. (CAN ENGR 2)

MAE272. Introduction to Manufacturing Processes (2)
Prerequisite: ME 172. Comprehensive survey of modern techniques in manufacturing processes. Basic manufacturing processes, nature and properties of materials; production of metals; foundry, casting and heat treatment; welding, powder metallurgy (sintering), plastics, metrology; working of metals, press work; machine tool elements, numerical control; metal cutting and turning; drilling, boring, milling; shaping planning, sawing broaching; grinding, sanding; gears and gear-cutting, threads and thread-cutting. (Lecture-problems 1 hour, laboratory 3 hours.) Traditional grading only.

Concentration in communications

Our program has one concentration in communications consisting of 12 semester units. The table below shows the courses covering this concentration. Following the table is a listing of the courses including the catalog descriptions. The concentration courses cover communications in regards to teaching (CECS 310E), learning (ENGR 400E), problem solving and design (ENGR 304), and business practices (ENGR 310). Several breadth courses lay the foundations in communications: for designing teaching tools based on modern electronics technology (CECS 110 & 200), for design and manufacturing (ENGR 172 & 272), for problem solving and design (CECS 401E & ENGR 375I), and for learning (ENGR 302I & 370I)

Table 2. Concentration courses

The concentration in communications requirements	Semester units
CECS310E Computer Based Learning Resources	3 units
ENGR304 Engineering Problem Solving & Design	3 units
ENGR310 Business Comms. in Engrng Profession	3 units
ENGR400E Engineering for Teachers	3 units

Total of 12 semester units. 25% of subject matter program.

Concentration Course Descriptions[6]

CECS Courses

CECS310E. Computer-Based Learning Resources (3)
Prerequisite: Some Internet experience. Explore and learn to use the many existing web-based education tools that focus on teaching technology. Evaluation of resources for age appropriateness and gender preferences. Students will develop a web-based tool to teach a technical subject of their choice. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

ENGR Courses

ENGR304 Engineering Problem Solving & Design (3)
Prerequisite: MATH 117 or three and one half years of high school mathematics, including algebra, geometry, intermediate algebra and one half year of trigonometry. The problem solving process: Definition, Solution alternative, and Implementation. Problem

Copyright © 2004, American Society for Engineering Education

solving tools: Analytical, Graphical, and Computer based. Procedures for creative problem solving. Nature of engineering design to meet a need. Design process overview. Critical thinking exercises using real-life examples. Team projects: Written reports and oral presentations required. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

ENGR310. Business Communications in Engineering Profession (3)
This course provides basic concepts for understanding and practice of communication in the changing world of business for managers and professionals. It examines the use of language and conversations in business settings and their role in coordinating actions, resolving breakdowns in work performance, and providing customer satisfaction. Course topics include: Practice in professional styles of business writing and formats, preparation of a formal report, development of competence in business conversation skills (written, electronic, and oral), and other selected topics. International,
technical, and linguistic developments are integrated into various applications of business communication. (Lecture –Discussion 3 hours.) Traditional grading only.

ENGR400E. Engineering for Teachers (3)
Prerequisites: MATH 119A or three years of high school mathematics including algebra, geometry, and intermediate algebra. Learn how engineers solve problems for humanity. Explore the various engineering disciplines and learn how they relate to mathematics and science. Discover how things work. Build engineering projects. (Lecture 2 hours, laboratory 3 hours.) Traditional grading only.

Conclusion

The realization that a secondary school education often provides very little exposure to the principles and practices of Engineering, and in light of the fact of declining enrollments in Engineering colleges and more and more reliance on a foreign high-tech workforce, it is imperative that we encourage more high school graduates to choose a career in Engineering. The object of the new program, a BS in Engineering Technology, Option in Technology and Engineering Education (along with the thirty units of post-baccalaureate coursework to receive a Clear Single Subject Teaching Credential in Industrial and Technology Education) is to provide teachers for public schools who understand the engineering discipline and it role in development and use of technology, and furthermore can convey the utility and rewards of a career choice in the field of Engineering to the college-bound student.

Bibliography

1. *"Standards for Technological Literacy: Content for the Study of Technology", International Technology Education Association, April 2000.*

2. *The California State Board of Education K-12 Content Standards (http://www.cde.ca.gov/standards/)*

3. *US Bureau of Labor Survey (2000).*

4. *Memorandum from Beverly L. Young, Assistant Vice Chancellor, Teacher Education and Public School Programs, California State University, Long Beach, November 4, 2003.*

5. *CCTC Industrial and Technology Education Standards, California Commission on Teacher Credentialing, 1999.*

6. *The California State University, Long Beach Catalog, Volume 55, April 2003.*

Copyright © 2004, American Society for Engineering Education