This Bird is Just Sleeping: the Future of Electrical Engineering Education in Computer Engineering Environments.

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Abstract

Many educators and commentators anticipate the withering of the 'traditional' Bachelor of Science in Electrical Engineering (EE) and the concomitant flowering of the Bachelor of Science in Computer Engineering (CompE). National trends and statistics support this shift in educational training. To go along with this tendency is recognition that over the past century there have been significant shifts in the domain encompassing EE:

Power transmission/rotating machinery to electronics;
Vacuum tube technology to semiconductors;
Discrete circuits to integrated circuits;
Analog electronics to digital electronics;
Fixed devices to programmable digital hardware.

By natural extension, the design of computer architectures, with relevant concepts and theories, and concurrent 'hands on' practice are considered a part of the educational experience of students needed to ensure success in the modern industrial/corporate environment. Hence the rise of CompE with its 'classic' complement of subject matter: basic science and math, network theory, electronics, digital systems, programming concepts, data structures, and operating system principles. EE education has always had a 'lagging' characteristic – changes in the educational product follow trends in technology. In spite of these forces, EE can, and will, play an increasingly pivotal role in meeting the technological needs of the world. The very rise of the computer has greatly enhanced the capacity for modeling that has always characterized EE – it is the 'modeling' art. While currently having relatively low profiles, many technologies are on the verge of explosive growth. While many talk of automation as a significant specialization, its true impact on technology is yet to be felt. New areas of expertise such as the exponentially growing field of telemedicine will require those skills more readily acquired through EE training. However, EE programs will need to redevelop a focus to best meet those needs. Such programs should avail students of well defined avenues of study suited to specific concentrations. The bird is not dead – it is only sleeping (from a Monty Python skit).

I. Introduction

The EE engineering profession and its educational support system recognize change as an evident fact of technological evolution. Changes have been brought about by several factors including growing industrial competition and accompanying corporate restructuring, and the explosion of information technology[1]. In order to manipulate more complex systems and to explore designs in an economically and ecologically sound manner, EEs have come to rely on extensive use of computer modeling; this is consistent with the evolution of the EE.

Prior to 1900 EE was primarily concerned with the generation and transmission of electric power as well as its uses with respect to rotating machinery. With the advent of the vacuum tube, EE entered the "electronic age" which 'flourished' in response to the needs of World war II. The semiconductor replaced the vacuum tube after the 1950s as the principal component of design and when the transistor became integrated into larger entities ("integrated circuits"), functional design replaced discrete component calculations. In a concurrent manner, digital electronics and concepts came to replace analog solutions – although a primary interface to the physical world remains one vestige of analog technology. Recent history records the newest shift from fixed (dedicated) devices to programmable digital hardware.

Changes in educational programs in the United States have paralleled historical developments in EE. It is difficult to find a B.S. in Power Engineering degree program. It is becoming increasingly easier to find "EE" centered programs that prepare students to work with both the hardware and software of the digital computer. With the rush for educational institutions to shift to CompE programs (within EE departments), it is possible for traditional EE programs to be supplanted just as the 'electronics' based EE degree has supplanted the EE power engineering degree.

II. Professional Demographics.

Recent career and professional trends in the United States reflect technological changes that have taken place over the past decade. [2,3] The U.S. Department of Labor projects the need for over 350,000 Computer Engineers and Scientists over the next decade. While EE has replaced Mechanical Engineering as the predominant (engineering) field, computer (hardware/software) engineering is growing rapidly. (In government surveys, 11 percent of all engineers report software engineering as their primary field .[2] *This discipline was not even reported in 1972*.). A recent survey of mid- and large-size companies in the United States concluded that some 190,000 information technology jobs remain unfilled due to a shortage of qualified workers. Other studies (e.g., Coopers & Lybrand) report that companies had inadequate numbers of information technology workers (including Computer Engineers) to staff their operations.

Even among all engineering disciplines, 58 percent of respondents report that computer applications are a common work activity. (This is only exceeded by design activities which are reported by 66%.)

III. Educational Trends.

Formal, four-year educational programs currently produce a small proportion of graduates properly prepared for this computer-based age. Only 24,500 U.S. students earned bachelor degrees in computer and information sciences in 1994 as compared to the projected need of some 350,000 over the next decade – a projected shortfall of some 100,000 graduates.

Computer technology, at the forefront of public awareness, further increases demand for CompE. Recent educational trends show an increase in interest in this discipline. As noted in the September 1997 issue of ASEE Prism, while overall declining enrollment figures in engineering suggest stagnation in engineering programs for most disciplines, only "Electrical and Computer" engineering enrollment for first-year, full-time, undergraduate students, shows an increase of 7.7% from fall 1995 to fall 1996 figures.

National trends[4], as noted in Tables 1 and 2 indicate that the number of EE degrees awarded from 1992 to 1996 has declined by some 36% while the corresponding decline in CompE degrees has been negligible, attesting to student interest and enrollment robustness of CompE degree programs.

Table 1
Electrical Engineering Degrees Awarded, 1992-1996

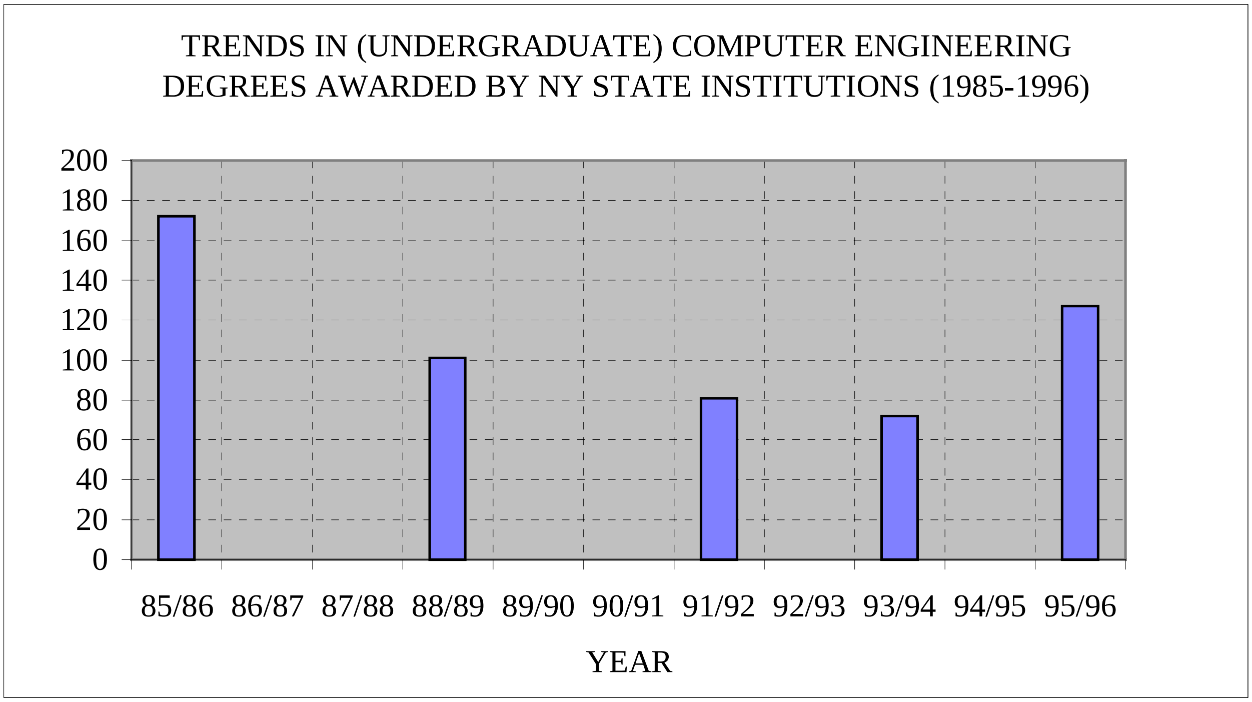
	1992	1996
Number of Reporting Institutions	187	161
Number of Degrees Awarded	15260	9817
Average Number of Degrees Awarded	81.6	61.0

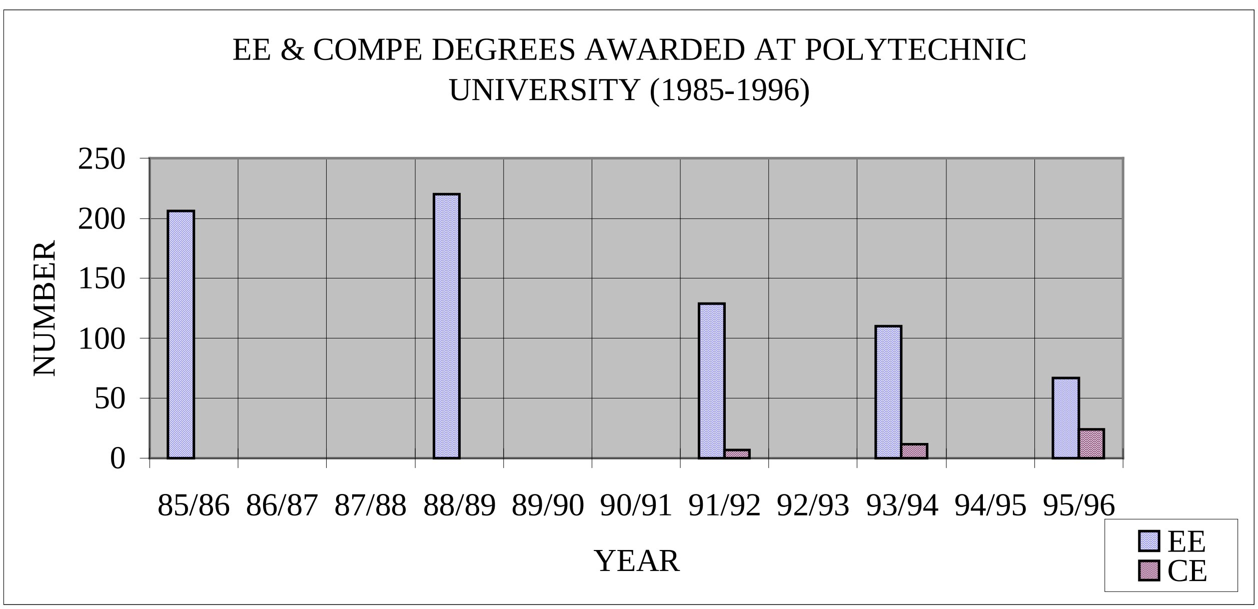
Table 2
Computer Engineering Degrees Awarded 1992-1996

	1992	1996
Number of Reporting Institutions	81	74
Number of Degrees Awarded	4550	3916
Average Number of Degrees Awarded	56	53

Local trends as described by similar statistics from New York state (for example) provide more detailed evidence which mirror national trends – see graphs below[5]. New York state has shown an increasing number of CompE degrees in its most recent history with the latest number of (CompE) degrees awarded being the largest since 1985. One prominent institution, Polytechnic University, shows a decline of EE degrees together with an increase in CompE degrees which now comprise 26% of the combined (EE/CompE) total.

With the well documented trends noted above, traditional EE programs are likely to wither. Educational institutions have rapidly developed CompE programs in response to the national demands to prepare students for the emerging information age.


TRENDS IN (UNDERGRADUATE) COMPUTER ENGINEERING
DEGREES AWARDED BY NY STATE INSTITUTIONS (1985-1996)
200
180
160
140
120
100
80
60
40
20
0
85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96
YEAR


EE & COMPE DEGREES AWARDED AT POLYTECHNIC
UNIVERSITY (1985-1996)
NUMBER
250
200
150
100
50
0
85/86 86/87 87/88 88/89 89/90 90/91 91/92 92/93 93/94 94/95 95/96
YEAR
EE
CE

I. Representative Computer Engineering Curriculum

While CompE programs differ in many details in order to meet institutional missions, most include several well defined topical areas intended to meet the demands of ABET. These programs are also consistent with training individuals to be aware of both practical and theoretical issues in Computer Engineering. Topics include: Basic laboratory science; Math; Humanities; Electrical Networks and Systems; Electronics; Digital Systems and Microcomputers; Programming Concepts; Data Structures and Algorithms; Operating System Principles. A representative program, similar to one developed at Manhattan College and recently registered with the Department of Higher Education of the State of New York is shown below (in its topical form):

Representative Computer Engineering Curriculum

Sem 1	Sem 2	Sem 3	Sem 4	Sem 5	Sem 6	Sem 7	Sem 8
Calc	Calc	Calc	Diff. Eq.	CompE Core	CompE Core	CompE Core	CompE Core
Chem	Phys	Phys	Statistics	Discrete Math	Discrete Structures	Systems Prog.	Op. Systems
Intro to Eng.	Intro to Eng.	Comp. Sci.	Comp Sci.	Algorithms	Comp. Arch.	Telecom	Tech Elect.
Writing	Hum.	Dig. Sys.	Micros.	Sig/Sys.	Sig/Sys.	Tech Elect	Tech Elect
Hum.	Hum.	Eng Science	EE Systems	Electr.	Electr.	Electro-Mag.	Hum.
			Hum.	Hum.	Hum.	Hum.	
16	16	16	18	16	16	18	15

Contemporary CompE programs are enriched with Humanities (Hum) to meet industry needs for individuals with communication and teamwork skills as well as business and management training. In such programs societal and political concerns increase attention to the needs of the public sector, public service, and public policy deliberations. The CompE Core forms the heart of the design portion of the program. This complement of four courses is built on a "bottoms up" philosophy in which students progress from modules with simple, highly structured, assignments, organized to reproduce techniques explored in such courses as Digital Systems, Electronics, and Computer Architecture to modules that are largely unstructured wherein students gain insights into the creative aspects of CompE.

I. New Roles for Electrical Engineering

With the evolution of the CompE emphasis, EE preparation provides an opportunity to train individuals for new roles linked to applications of the computer and which use such resources as tools for meeting the needs of newly emerging technologies. Rapidly changing and emerging technologies for which the demand is likely to grow in the near future include such areas as:

Robotics, Image Processing, Optics, Communications, Automation, Artificial Intelligence, and Biomedicine.

The Institute of Electrical and Electronics Engineers (IEEE) recognizes some 38 technical councils reflecting the broad professional interests of its membership. This spectrum of interests exceeds those of the other engineering disciplines mirroring the potential provided by training in EE. A few of these councils include: aerospace, communications, control systems, engineering management, medicine and biology, information theory, transportation systems, oceanic engineering, signal processing, optics, robotics, geoscience, environment, health and safety, social implications of technology, and vehicular technology. (This list does not include the more traditional electronic interest groups.)

In order to meet the needs of those constituencies concerned with emerging national interests (but not necessarily in current demand), an opportunity exists for new directions in EE education. For example, in addition to basic training in Science, Math and the Humanities, a complement of course work in digital signal processing, information theory, statistics, artificial intelligence, automation, and simulation, (in addition to some of the traditional EE topics of network analysis, electromagnetics and electronics) could provide a strong foundation for a number of the professional interests cited above. An aggregate of such courses would not necessarily require an extraordinary complement of faculty expertise and thereby limit additional economic stress on educational institutions.

II. Conclusion

The current popularity of CompE programs provides an opportunity to rethink the purposes and design of the traditional EE curriculum. Such revised EE programs would serve emerging technologies. It would also fill an educational void that is certain to emerge once institutions have migrated from EE programs to CompE programs. The "(EE) bird is not dead" as a popular TV comedy program once noted (Monty Python), "it is just sleeping."

Bibliography

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Currently Professor of Electrical Engineering at Manhattan College, Dr. Silverman has had over 40 years of experience in industry, research and education. During this time he has served as department Chair and Co-Director of a government supported facility for microprocessor research. He has also served as a consultant to the technical publishing industry, has authored four technical books, published numerous papers and holds eight patents. His current interests include computer applications in biomedical automation. Dr. Silverman holds degrees from Columbia and Polytechnic Universities. He can be reached at gsilverm@manhattan.edu.