TStudying Artificial Intelligence and Artificial Sociality in Natural Sciences, Engineering, and Social Sciences: Possibility and Realityʏ

Dr.V.H.Prasad,K Naresh Kumar,M Shailaja
Professor[1],Associate Professor[2,3],
Dept. of CSE,
mail-id: nareshk03@gmail.com, shailajacse@anurag.ac.in
Anurag Engineering College,Anatagiri(V&M),Suryapet(Dt),Telangana-508206

Abstract—The authors will briefly describe how some of today's innovations and advancements might provide potential for improving the efficiency, effectiveness, and quality of contem- porary teaching methods. A model curriculum proposed in this paper merges the disciplines of mathematics, science, engineering,and computing. It also addresses the growing need for exposing aspiring engineers to the human, cultural, and professional aspectsof their emerging careers.
Index Terms—Electrical and computer engineering (ECE) cur-riculum, future of electrical and computer engineering education, undergraduate.

INTRODUCTION

PROGNOSTICATION about matters associated with the advancement of technology is always a risky endeavor. History is filled with examples of visionary experts whose pre- dictions were a bit off the mark. For example, when computers were first created, T. J. Watson, the founder of IBM, predicted the need for six computers worldwide. Ken Olsen, the founder of Digital Equipment Corporation (DEC), believed that no one would ever have a computer in his or her home. Bill Gates, the founder of Microsoft, was once reported as saying that 64 kB should be enough storage for anyone. Even though these pio- neers were experts and led major technological advancements, their ability to determine the ultimate impact and direction of technology was unremarkable in many cases. The examples the authors chose are serendipitous in that each is a huge underes- timate of the astounding success of these innovations. Other innovations, such as the Internet and personal communications, are touching the lives of a significant proportion of the entire population of the earth. Few, if any, could have predicted the pervasive public adoption of these ideas. Nevertheless, the authors of this paper embrace the challenge of attempting to foretell the "future of Electrical and Computer Engineering (ECE) education." Unlike the aforementioned pioneers, the benefit of the 120-year history of engineering education is a basis for extrapolation. If history proves that the authors, like these pioneers, are unable to foretell the future accurately, they sincerely hope it will also show that they were as successful.

A. 1882

The roots of electrical engineering are firmly based on the science of physics. In 1882, the Physics Department at the Massachusetts Institute of Technology (MIT), Cambridge, offered the first optional course in electrical engineering [1]. Soon after, other physics departments across the country followed suit. The firm and important relationship between science and engineering was recognized at the very birth of engineering as a field of study.

B. 1903–1940

The year 1903 saw the beginnings of an ever-growing dia- logue and relationship between educators and members of in- dustry. At a joint meeting of the American Institute of Elec- trical Engineers (AIEE) and the Society for the Promotion of Engineering Education (later known as the ASEE), industrial- ists presented papers suggesting which engineering principles should be taught [1]. This input prompted change in electrical engineering education. Indeed, in the years from 1900 to 1935,electrical engineering education lost much of its cultural identity because of pressure from the industry to teach industrial skills,facts, and methods suitable for the practice of electrical engi- neering. The emphasis for engineering education was on design codes and structured methodologies [1]. Major advances, suchas radio and radar, were all but overlooked by electrical engi- neering educators of this period.

From 1907 to 1918, the Society for the Promotion of Engi-neering Education (SPEE) with the help of the Carnegie Foun-dation conducted several studies of engineering programs. Theresults of these studies were issued in a report that encouragedengineering programs to focus on the intellectual developmentof students and not just the teaching of facts and methods. Ad-ditional surveys of engineering programs from 1923 to 1929 by Wickenden led to the formation of the Engineering Council for Professional Development (ECPD). The ECPD was charged to develop an accreditation process for engineering programs [1]. In 1940, the SPEE presented another report [1] calling for the addition of subject matter in the areas of the humanities and

social sciences. This report began the reincarnation of electricalengineering education, which culminated with the Grinter report [2] in 1955.

C. 1955

In a landmark paper evaluating engineering education over a three-year period, Grinter recommended that all engineering curricula include the following common set of courses in the "engineering sciences":

Mechanics of Solids;

Fluid Mechanics;

Thermodynamics;

Heat and Mass Transfer;

Electrical Theory;

Nature and Properties of Material.

The report also recommended that engineering curricula in- clude coursework in the social humanities. This recommenda- tion was clearly aimed at helping engineers to develop skills in interacting with people and to understand the social ramifica- tions of technological development. This report had a founda- tional impact upon engineering curricula and firmly rooted the study of engineering in the sciences.

D. 1978

In 1978, members of industry, commissioned as the ad hoc IEEE Model Curriculum Committee, issued a controversial rec- ommendation in their paper "A Model Undergraduate Electrical Engineering Curriculum" [3]. As in 1903, this model curriculum was born out of industry dissatisfaction with the contemporary electrical engineering curricula. The model recommended in- creased emphasis on the following areas:

communication skills;

economics and political issues;

interpersonal relations associated with business;

iInterdisciplinary subjects.

These recommendations were aimed at addressing perceiveddeficiencies in graduating engineers. The controversy generatedby the committee's paper appeared to be directed at the incor- poration of the softer social sciences and interpersonal skills de- velopment that might dilute the intense emphasis on science and technology characteristics of engineering curricula. The feelingof many engineering educators at that time can be summarized as follows: " the reemphasis of the past [2] interests can be a beneficial reminder that although they must be concerned about the socially oriented problems of today (1978), the purpose of engineering schools is to educate engineers and not social sci- entists" [3].

Around this same time, in an article prepared for the IEEE TRANSACTIONS ON EDUCATION, Trautman presented his vi- sionary ideas on the new "Frontiers in Education" [8]. He envisioned the following five exciting new areas that would influence electrical engineering education pedagogy:

the dynamics of learning—self-learning and mediated learning especially via the interactive computer;

the interplay between student and teacher—an emphasis on renewing competencies and a paradigm shift to the teacher as the stimulator of student learning, as contrasted

with the more traditional approach of the teacher as the transmitter of learning content;

the handling of cognitive and affective individual differ-ences and recognition of cultural differences that influ- ence the manner in which people learn;

a new symbiosis of technology and society—how goals are set and by whom, and technology literacy for all;

the continual renewal of the four-year curriculum.

E. 1994

In 1994, the National Science Foundation (NSF) established various Engineering Education Coalitions, named ECSEL, GATEWAY, SUCCEED, SYNTHESIS [6], FOUNDATION

COALITION [7], etc., for the purpose of initiating funda- mental improvements in and creating innovative pedagogies for engineering education. Some of the topics addressed by these coalitions were: design across the curriculum, new cur- riculum models for the next century, developing an integrated curriculum, open-end problem solving using multidisciplinaryskills, and the development of curriculum based on first principles.

Trautman's vision of more than a decade earlier appears to have had significant influence on the Engineering Education Coalitions effort supported by the NSF. Moveover, there is mounting evidence that measurable results can be attributedto the coalitions' efforts. The literature reports several new integrated-curriculum successes, such as the programs at Louisiana Tech University, Reston [9], North Carolina State University, Raleigh [10], and Texas A&M University, College Station [7]. In addition, open-end problem-solving/entrepre- neurial programs were emerging at many institutions, such as the "Engineering Design Thread" at Rose-Hulman Institute of Technology, Terre Haute, IN [18], supported by the FoundationCoalition [7].

F. 1995

From the findings of a series of consensus-building work- shops, the Accreditation Board for Engineering Education (ABET) issued a summary report entitled “The Vision for Change” that proposed a drastic downsizing of the criteria, a re-orientation of its accreditation philosophy, and constructive interaction with its constituency. The call for reform was in response to an undeniable paradigm shift in engineering edu- cation and was intended to help overcome barriers considered overly stifling to educational innovation. The paradigm shift acknowledged by ABET and others in industry and academe during this period did not abandon the solid mathematical and scientific base of contemporary curricula; however, it did sup-port a new emphasis on teamwork among students and a new awareness of economic, social, and environmental concerns expected to mark the leaders of the twenty-first century.

G. 2001

Increasingly faced with the problem of trying to keep up with the rapid advances in technology without adding material to overburdened four-year engineering curricula [11], ECEDepartments began to develop more specialized curricula. This

curricula can be seen in the report of the joint IEEE ComputerSociety/Association for Computing Machinery (ACM) TaskForce (CC-2001) [12]. The Task Force was commissionedto review the 1991 report [5] and to develop a revised andenhanced version for the year 2001. This endeavor involvedthe creation of several “volumes” reflecting the diversity of thecomputing field; for example, Computer Science, Computer Engineering, Software Engineering, Information Systems, plus an Overview volume. Respondents to a CC-2001 survey “ expressed interest in having the final report define more model curricula with particular emphasis on the diverse nature of educational resources, systems and requirements at different academic departments throughout the country and the world.The survey results also strongly suggest that the revised cur-ricula should pay proper attention to the accreditation criteria for both CS and CE programs.” Each of the volumes is under the control of separate committees and has been published uponcompletion. Once the entire set is completed, it should serve asa benchmark for the comparison, refinement, and developmentof future programs in the area of computing. Furthermore, themerging of ABET and Computer Science Accreditation Board (CSAB) may result in other combinations of computing-re- lated undergraduate programs in engineering being created inaddition to those identified in CC-2001. Clearly, the CC-1991and CC-2001 reports have the potential to have an impact oncomputing-related education comparable to that which theGrinter report [2] of 1955 had on engineering education.

The Emergence of Conflicting Trends in Engineering Education

Kulacki and Krueger [13] suggest that in the next few years, engineers will enter into a professional environment that is dominated by knowledge-based industries. Developing economies will rely on the “brain power” of engineers to solve problems using the fundamentals of science. This outcome suggests that engineers who have the attributes of adaptability,flexibility, and a profound ability to learn will be best suitedto serve the long-term needs and viability of industry and de- veloping economies. Therefore, a general or generic educationthat emphasizes the development of problem-solving skillsbased on a deep understanding of engineering and scientific principles will best prepare engineers to meet the demands of their constituency. Furthermore, these attributes will be all themore important as the globalization of industries, markets, etc.,continue to develop and expand [13].

Mickleborough and Wareham [14] and Ditcher [19] seemto support the Kulacki and Krueger [13] argument for a more generic engineering education. Mickleborough and Wareham

[14] presented evidence that the overload of content in engi- neering curricula leads many students to take an opportunistic approach to their studies. This approach is marked by a moti- vation to pass exams in order to obtain a degree, rather than being driven by a desire to learn. As a result, students retain lessand do not develop the ability or desire to learn. *Therefore, a case can be made for generic undergraduate degree programsin engineering.*

On the other hand, many universities, faculty members, andaccrediting agencies are becoming entrepreneurial in their ap- proach to developing engineering curricula by appealing to theperceived needs of the worldwide industry that, in turn, is beingdriven by accelerated advancements in technology and marketopportunity. Examples of this curricular entrepreneurship can be seen in the number of new engineering degrees beginning toappear.

The Cellular Telephone Industry Association [15] conducteda study on the availability of radio frequency (RF) curricula andfound a severe shortage of schools offering any RF education. This study revealed that RF courses have been replaced by more fashionable courses in computer science and software engineering. However, the unprecedented success of personal and wireless communications has fueled technological ad- vancements in virtually every aspect of electrical and computer engineering. The astonishing worldwide growth in these areas can only be supported if educational institutions commit to de- veloping a new generation of wireless professionals, especiallyin RF engineering. The predicted shortage of such specialistsis so great that it has fostered a spirit of collaboration between industry and academia to institute curricula and accelerate the emergence of qualified engineers and technicians. Enter the Global Wireless Education Consortium (GWEC), Arlington, VA, a nonprofit organization established in 1997 [15].

GWEC is an industry/academia partnership initiated by industry and collectively focused on expanding wireless tech- nology curriculum in academic institutions worldwide in an attempt to address the workforce shortage that is expected to reach crisis proportions. GWEC has helped in the establishment of a growing number of undergraduate wireless programs in both two- and four-year academic institutions. Even with the current downturn in the economy, GWEC member compa- nies remain committed to the long-term need for skilled and knowledgeable employees in this burgeoning technological field. As applications for wireless technology expand beyond the telecommunications sector into areas such as medicine andautomotives, universities also recognize the value to students of up-to-date wireless education and exposure.

The recent announcement by Auburn University, Auburn, AL, is a notable example of curricular entrepreneurship within the wireless arena. Auburn University received $25 million to develop an undergraduate degree in wireless engineering. Thisprogram will be an interdisciplinary effort that involves facultyand programs in two departments: ECE and Computer Scienceand Software Engineering. Students will be able to specialize in hardware, software, or networks.

Other experiments in niche areas of technology are the Optical Engineering degrees at the University of Arizona, Tuc- scon; University of Alabama, Huntsville; and the Rose-Hulman Institute of Technology. These degrees are even narrower than the Wireless Engineering degree being developed by Auburn University. Furthermore, programs in control engineering, system engineering, and power engineering have been around for a number of years and similarly represent specialized areasof teaching and learning.

This entrepreneurial spirit in education is affirmed in the number of new degrees and partnerships that have been created.

TABLE I
UNDERGRADUATE SPECIALIZATIONS AND A FEW OF THE SUPPORTING PARTNERSHIPS

Electrical Engineering (BS) [28]
Systems and Control Engineering (BS) [28]
System Engineering (BS and BSSE) [28]
Wireless Engineering (BS) [28]
Engineering (BS) [28]
Engineering Physics (BS) [28]
Optical Engineering (BS and BSOE) [28]
Electrical and Computer Engineering (BS) [28]
Computer Engineering (BS) [28]
Telecommunications Engineering (BS) [28]
Computer and Systems Engineering (BS) [28]
Software Engineering (BS) [28]
Computer Science (BS) [28]
Partnerships
ABET and CSAB [28]
Global Wireless Education Consortium
IEEE and ACM

Therefore, motivation and recent actions support the viability and need for the development of targeted undergraduate degree programs in engineering to meet the needs of industry. Table Ilists currently known undergraduate specializations and a few of the supporting partnerships.

Clearly, two apparently opposing views have emerged with a multitude of specialized curricula on one end and general- ized or generic curricula on the other. Each of these approachesprovides value in different ways. Both should be measured by the breadth and depth of knowledge they develop in emerging graduates and the degree to which they prepare graduates to make professional contributions. Either approach appears ca- pable of fulfilling the long-term needs of industry and devel- oping economies. The value of a general curriculum is linked to the breadth or scope of technical contribution that emerginggraduates are prepared to deliver. In contrast, the value of spe- cialized curricula is linked more to the depth of technical con- tribution that graduates are prepared to deliver. Clearly, there may be profound value in both approaches, but there are also down sides.

Each approach seeks to handle the conflicting constraints imposed by the accelerating pace of technological advance- ment versus realistic limitations on the scope of content thatan undergraduate curriculum can realistically deliver. While specialized curricula may provide sufficient depth of contentto allow entry-level engineers to make more immediate con- tributions, their benefits must be afforded by eliminating one or more fundamental courses, possibly limiting the ability of emerging specialists to grow and evolve with disjoint techno- logical advances. An increased rate of technical obsolescence may indeed be a by-product of a curriculum that is too narrow or specialized. Educational institutions must also be careful to ensure the long-term relevancy of both

proposed specializations taken as a whole, as well as the constituent courses. Further-
more, the emergence of new specializations will introducenew challenges in accreditation and standards for entry into advanced degree programs. Clearly, undergraduate specializa- tions may have strong appeal and value to industries engaged in technical disciplines that require a substantial degree of specialized knowledge beyond that provided by traditionalengineering curriculums. Well-developed specializations may indeed reduce the costs of corporate training at the entry level. However, one must consider that the savings at the entry level may be offset by an increase in costs to replace or retrain an experienced professional workforce as technological advancescontinue.

The greatest advantages of a generalized undergraduate cur-riculum are aimed at providing entry-level graduates with a pro- found understanding of broad and universally important princi- ples, as well as abilities to learn and adapt to technological ad- vances. However, practical limitations on the volume and scopeof curriculum content have not kept pace with the specialized knowledge required to make relevant technical contributions at the entry level. Specialized knowledge is often gained at corpo- rate expense through "on-the-job" training or financial support for graduate studies. Furthermore, corporate support for training and graduate studies has become increasingly risky. Industriesexperiencing a professional workforce shortage are often forcedto compete for the services of the very people they trained.

While the authors suggest that both approaches may be nec-essary to support the needs of the global community taken asa whole, the ramifications of a large-scale paradigm shift to- ward undergraduate specializations are not well understood. In light of this situation and the down sides discussed previously,the authors favor a more general engineering curriculum as thepredominant mode of undergraduate engineering study. In other words, although the authors foresee the need for both undergrad- uate specialists and generalists, they believe that specializationsmust be driven by the long-term universal needs of the engi- neering communities of interest and profound insight in devel-oping curricula that serve the long-term career interests of theirgraduates. The authors further believe that the needs of the engi- neering community will continue to diversify, and a general cur- riculum that attempts to optimize over the conflicting attributesof generality and specialization will also be of great value and may indeed have the strongest appeal.

This latter approach may be based on a refinement, evolu- tion, and merging of traditional engineering curricula. Such anoptimized curriculum may be embodied in a combined degree in ECE. Computers, processors, and computer technology have become important in virtually every aspect of electrical engi- neering, especially in areas associated with signal processing, control systems, etc. Likewise, the importance of electrical engineering fundamentals is becoming increasingly vital inthe development of faster and more powerful computers and computer architectures. Computers are already operating at speeds requiring an understanding of microwave phenomena. As a result, the distinction between electrical and computer engineering is being obviated. This observation is supported by the National Electrical Engineering Department Heads Association (NEEDHA) meeting in 2001, whose membersvoted to change their name to the Electrical and Computer
Engineering Department Heads Association to better reflect the state of our profession. Furthermore, Worcester Polytechnic Institute, Worcester, MA, and Baylor University, Waco, TX, areexamples from academe that are pursuing this same solution [16], [27]; other examples are [28] and [29]. The authors recognize that other generalized programs can be conceived by merging or expanding traditional criteria that would support a variety of needs, but the authors believe that the merging of electrical and computer engineering has the widest appeal and value.

A View of Electrical and Computer UndergraduateEngineering in 2013 and Beyond

There is no doubt that the undergraduate curriculum and thequality of its delivery are at the heart in shaping the professionallife of an engineer and the degree to which he or she will be suc- cessful. The content must be relevant to the engineering commu- nity, and the pedagogy must ensure that students have a solid understanding of engineering principles and the ability to think. Furthermore, the curriculum must stimulate the motivation anddevelopment of both students and faculty [17]. In this section, the authors first propose a model for content and later offer theiropinions on how teaching techniques may evolve.

Clearly, the quality of a curriculum and its delivery are two of the fundamental measures by which the engineering commu-nity will evaluate educational institutions. While the notion of quality is always multidimensional, two important and related dimensions are relevance of the knowledge base provided and the ability of entry-level engineers to make immediate contri- butions. Obviously, the end customers are the students and theengineering community that provide and constitute the profes-sional environment they enter. While industry and government play a predominant role in determining the professional engi- neering environment, educational institutions should not lose sight of their responsibility to address the needs of academic, humanitarian, and national interests. With these ideas in mind,curriculum goals and objectives are stated.

Goals

In establishing these goals, the authors borrow heavily from Hira [17]. At the highest level, the curriculum should have the following goals:

provide students with the ability to enter professional prac-tice;

be broad enough to enable students to pursue careers inother professions;

relate engineering to broader needs;

provide intellectual and professional growth for the fac-ulty.

Curriculum Objectives

In order to attain these goals, the curriculum should have thefollowing objectives:
a fundamental and rigorous foundation in mathematics, science or engineering science, traditional electrical engineering topics, and traditional computer engineeringtopics;
a fundamental development of a second language;
an understanding of professional practice, includingethics;
as many elective opportunities as possible for the studentand faculty to develop plans of study.
Based on these objectives, the authors propose the four-yearcurriculum found in Table II.

Mathematics Core
The mathematics core will continue to include the tradition of rigorous emphasis on calculus and differential equations. Dis- crete mathematics is included, given its growing value to the computer engineering community. Discrete mathematics intro- duces mathematical logic, set theory, relations, and functions of finite-state machines. It will build on Digital Systems 1 andprovide a solid foundation for Digital Systems 2 (see Section IV-E). Courses in probability and statistics are included to pro-vide foundations for elective areas such as communication, con- trols, and artificial intelligence (AI). Finally, a math elective isprovided to enhance and expand the mathematical awareness and analytical capabilities of graduates. Electives may includereal and complex variables, stochastic processes, and queuing theory.

Physics, Engineering Science or Science, and ElectronicDevice Modeling Core
A three-course sequence in classical physics will continue tobe fundamental to the electrical engineering curriculum. The topics discussed in classical physics will be reinforced in the electrical engineering core. The expanded choice of science or engineering science electives reflects the increasing rate at which fundamental breakthroughs are occurring in all science disciplines. The effects that such breakthroughs will impose on curricula will be measured in years, not decades. Therefore, flexibility in what is generally accepted as engineering sciencemay need to include electives in other fields traditionally attributed to disciplines in science. These electives may includemicrobiology, genetics, and chemistry and are aimed at equip-ping students with a fundamental knowledge base to exploit the value of new innovations in these fields. Therefore, the authors propose the following engineering science electives:
Statics;
Fluid Mechanics;
Operating Systems;
Chemistry;
Dynamics;
Thermodynamics;
Nature and Properties of Material;
Biology.
Electronic Device Modeling 1 and 2 will deal with the design, analysis, fabrication, and testing of analog linear and nonlinear electronic circuits preparing students for elective courses in very large systems integration (VLSI) and power electronics.

Computing Core
The following core set of courses and discrete mathematics will provide the foundation for elective courses in computer

TABLE II
PROPOSED ECE DEGREE

Year 1	Course	Hours	Course	Hours	Course	Hours	Course	Hours	Total
Fall	Calculus 1	4	Computer Science 1	4	English Composition 1	4	Physics 1	4	**16**
Winter	Calculus 2	4	Digital Systems 1	4	English Composition 2	4	Physics 2	4	**32**
Spring	Discrete Math	4	Computer Science 2	4	Technical Communication	4	Physics 3	4	**48**
2									
Fall	Differential Equations 1	4	Digital Systems 2	4	Eng. Science or Science Elective 1	4	Electrical Systems 1	4	**64**
Winter	Differential Equations 2	4	Computer Architecture 1	4	Eng. Science or Science Elective 2	4	Electrical Systems 2	4	**80**
Spring	Probability	4	Computer Architecture 2	4	Eng. Science or Science Elective 3	4	Signals and Systems 1	4	**96**
3									
Fall	Electromagnetic 1	4	Electronic Device Modeling 1	4	Language or Soc. Science 1	4	Signals and Systems 2	4	**112**
Winter	Electromagnetic 2	4	Electronic Device Modeling 2	4	Language or Soc. Science 2	4	Technical Elective 1	4	**128**
Spring	Statistics	4	Professional Practice 1	4	Language or Soc. Science 3	4	Technical Elective 2	4	**144**
4									
Fall	Math Elective	4	Professional Practice 2	4	Language or Soc. Science 4	4	Technical Elective 3	4	**160**
Winter	Free Elective 1	4	Professional Practice 3	4	Language or Soc. Science 5	4	Technical Elective 4	4	**176**
Spring	Free Elective 2	4	Technical Elective 6	4	Language or Soc. Science 6	4	Technical Elective 5	4	**192**

science, software engineering, and electrical and computerengineering:

- Computer Science 1 (algorithms, computer program- ming, elementary data structures, and object-oriented programming);
- Computer Science 2 (lists, stacks, queues, trees, and intro-duction to software engineering);
- Digital Systems 1 (basic combinational logic design, Boolean algebra, logic minimization, and finite-state machine design);
- Digital Systems 2 (design and evaluation of combinational and sequential logic circuits using programmable logic devices);
- Computer Architecture 1;
- Computer Architecture 2.

B. Electrical Core

The following core set of courses provides the foundation forelective courses in physics, wireless engineering, and electricaland computer engineering topics:

- Electrical Systems 1 (transient and steady-state behaviorsof circuits);
- Electrical Systems 2 (time-domain analysis of circuits,Laplace transforms, and power);
- Signals and Systems 1 (Fourier series and transforms,spectra, and modeling);
- Signals and Systems 2 (digital signal processing);
- Electromagnetic 1 (fields);
- Electromagnetic 1 (waves).

C. Professional Practice

This course sequence is intended to provide all students withan understanding of engineering ethics, professional develop- ment activities and related professional societies, various design methodologies, team organization and management, develop- ment of design-project specifications, general engineering eco- nomics, engineering decision-making processes, and oral and written communication skills [18]. *Composition and Language or Social Science*

The English composition and technical communication courses provide instruction in writing and analysis of expos- itory prose, the study of logic and principles of rhetoric, and the application of writing to technical letters, memoranda,proposals, and reports, written and oral.

Many high schools require two to four years of foreign lan- guage to qualify for an "academic honors diploma" [24]–[26]. Since secondary schools continue this push of adding foreign language requirements, ECE programs should prepare to take advantage of this trend. This language core will teach courses such as philosophy, psychology, and the arts in a foreignlanguage.

For those students who have not had the benefit of learning a foreign language in high school, social science courses and cultural diversity classes would be taken, aimed at expanding understanding of different cultures.

The last few decades have seen a dramatic change in where technological innovations occur and products are manufactured. This globalization will impose many new demands on human interaction.

D. Free Electives

Students will be encouraged to select courses in the hu- manities, such as history, economics, philosophy, psychology,biology, and the arts as their free electives. Such exposure remains essential to a well-rounded education. Integrated into all coursework, required and elective, will be elements ofteamwork, problem solving, critical thinking, and "hands-on" experience. These "soft skills" are critical to any workplace environment.

ASSESSMENT AND OBSERVATIONS ON THE PROPOSED CURRICULUM

The authors assert that a degree that lives at the intersection of science and engineering must be developed to ensure that new generations of engineers are able to thrive in a professional en-vironment of rapid technological and cultural change. Toward that end, they believe that a general curriculum that representsa true seamless merging of computer and electrical engineeringwill best prepare students to adapt to technological change. They believe that the model curriculum described previously, i.e., a combined degree in electrical and computer engineering, pro- vides the scope and content that undergraduates will ultimatelyneed to be effective in this new world. While the authors un- derstand the benefit of undergraduate specializations in certainareas, they do not support their widespread proliferation as en-compassing the general character of mainstream undergraduateprograms.

It is evident that the proposed curriculum is more an expan- sion and evolution of some of today's more effective general curricula than a completely new development. This fact is not surprising given that this curriculum is founded on goals and objectives that deal with needs at a level just above the technology level. The emphasis enhances engineers' abilities to communicate and learn in a world characterized by an increasing rate of technological innovation and global expan- sion. A dramatic change in curricula will accompany a major technological breakthrough that obviates the foundations uponwhich traditional engineering curriculums are based. Clearly, the technical subject matter must evolve to ensure currency andrelevancy of the required technical knowledge base. But more than ever, curricula must prepare students to thrive in a world of cultural differences and geographic diversity of unprecedented proportion.

A well-developed and well-delivered curriculum must pro- vide learners with a strong ability to think, especially by ap- plying well-understood principles. This ability is foundational in developing the attributes of adaptability and flexibility in the students. As globalization continues, these same attributes of adaptability and flexibility must be developed as they relate tothe human and societal aspects of their profession if instructors aspire to prepare students adequately to enter the professional environment.

Obviously, the evolution of engineering curricula must trackthe rapid changes in technology. More than ever, the evolution of an engineering curriculum must be a continual, proactive, and regularly planned activity. The increasing rate at which tech- nology is advancing dictates that curriculum development be driven to a much greater extent than ever before. Increased col-laboration among academia and industry to forecast technolog-ical advancements, and perhaps major paradigm shifts, will beessential to ensuring that educators are able to respond to the needs of its customers.

The emergence of specializations at the undergraduate level provides an interesting and yet-to-be proven opportunity to at- tract the attention of prospective students and specific sectors ofgovernment and industry. This approach essentially seeks to de- fine curricula based on "market" opportunity, thereby focusingon the needs of industry and government. While this approach may be attractive in securing the financial health of educationalinstitutions, it was noted previously that the long-term ramifi- cations of a whole-scale paradigm shift in that direction is not well understood. Clearly, there are issues and down sides and, perhaps, ethical concerns. The extent to which undergraduate specialization narrows the scope of undergraduate knowledge is of primary concern. Some of the possible effects have been discussed.

Again, technology is rapidly evolving. Care must be exercised to ensure that undergraduates have a sufficiently broad educa- tional experience to deal with and adapt to that evolution, evento the extent that their specialization may be obviated. Further- more, educational institutions must assume some responsibilityto ensure the long-term value of a chosen specialization, espe- cially if the curriculum does not prepare students to think out- side the field of specialization. The wireless specialization, ref- erenced previously, builds solidly upon foundational courses inengineering and computer science with virtually no dilution ofthe basics. It is viewed as sufficiently broad in scope —an exten- sion rather than a deviation or departure from core engineering knowledge and theory. Other specializations, however, may bemore narrow. The planning of a specialized undergraduate cur- riculum must also account for the limits, if any, it might imposeon graduate level education. In contrast, a general undergraduate education provides a proven path for students who wish to spe- cialize at the graduate level. FInally, the standards developed by accrediting organizations must also evolve to provide objectivemeasures of the quality of specialized engineering curricula and pedagogy. It is unclear as to how standards can be developed toaccount for a wide range of specializations.

PEDAGOGY

The next decade will provide unlimited opportunities for de- veloping new and improved methods for delivering curriculum content. The growing needs of continuing education from the industrial/professional sector, the ever-increasing pressure on academia to perform research and publish, and the growing costof delivering a quality education are a few of the key factors that will drive educational institutions to seek more effective and efficient methods of delivery. Specifically, educational institu-tions will place increased emphasis on improving the followingmethods:

- those that motivate students to learn on their own and re-tain knowledge;
- those that provide a deeper understanding of fundamental principles by developing methods for observing and/or ex- periencing them in action;
- those that reduce (but not eliminate) the amount of directfaculty involvement in delivering course content, while improving the quality of direct interaction with students;
- those that allow anytime, anywhere delivery;
- those that provide the ability to educate limitless classes while promoting an atmosphere of small class size or, better still, a "personal educator."

Enabling technological advances in AI, computing power and mass storage, computer-aided design, software analysis and simulation techniques, multimedia communications, virtual reality, etc., will allow institutions to make major advances in these directions. For example, they will allow novel ways of demonstrating principles, providing team and interactive learning experiences, and sharing information and laboratory resources among diverse locations and learning institutions. Indeed, interactive educational modules are achieving success as aides to teaching undergraduate courses in signals and systems, electronics, communications, etc., as demonstrated by Millard, the director of the Academy of Electronic Media Laboratory, Rensselaer Polytechnic Institute, Troy, NY [20].

An undergraduate electrical and computer engineering cur- riculum is limited in the number of courses, content, and scope.As such, there will be a significant opportunity for academia and commercial ventures to create complete evolvable course sequences that teach theory, provide for simulated lab experi- mentation, allow access to remote resources, and provide a wide array of opportunities to practice problem solving to reinforce and enhance the learning experience. The experience gained through the proliferation of these learning modules should lead to substantial improvements in the quality and consistency of content delivery.

Because the focus of traditional engineering curricula is lim-ited, there is a significant opportunity to select best-in-class pre-

sentations for the development of multimedia course material. By recording student actions in an interactive learning session, neural network and data mining techniques may be employed to uncover the characteristics of learning patterns and possible deficiencies in material and presentation. Based on these inter-actions and advances in AI, students should be able to interact with learning modules in a natural Q&A session, thereby re- ducing (but not eliminating) the need for faculty involvement. Elementary examples of AI are already commonplace, as is ev-ident in popular computer-based help agents, voice response systems, and computer-aided design tools. The presentation ofcourse material via interactive modules supported by periodic in-person meetings is already being employed [22], [23].

Increases in computing power, e.g., through massively par- allel computer architectures, will provide limitless opportunityfor illustrating complex principles, such as those observed in electromagnetic wave propagation. Advances in software anal-ysis will allow students to practice the use of modern tools to solve complex problems. Simulation techniques will provide students unprecedented opportunity to observe the behavior ofcomplex designs or scientific/engineering principles in a con- trolled semi-real-world environment. Virtual reality will actu- ally allow students to experience the result of their ideas in ways that were not dreamed of a decade ago. The Internet and other advances in data communications and networking tech- nology will provide, and to a great extent already does provide, “anywhere” participation. Work group and geographically dis- persed multidisciplinary-team projects will become common- place, allowing access to common resources, the generation of easily accessible experience and knowledge bases, and the fa- cilitation of collaboration among faculty, educational institu- tions, and interested members of the industrial/professional en- gineering communities. The possibilities are limited only by our own imaginations.

In light of the rapid advances in the aforementioned technolo-
gies, some of these ideas may seem unremarkable because some of them are currently being deployed. Exploiting the fuller po-tential will require a concerted effort on the part of educators, researchers, and the government/industrial sectors, as well as, of course, significant investment. Although grant funding has been available from government and foundational agencies to pursue ideas such as these, one might guess that the commercial oppor-tunities for both educational and industrial application are sub-stantial. If that were true, an entrepreneurial partnership among educational and commercial interests might draw sufficient in-terest from venture capitalists to realize the full benefit of theseopportunities.

SUMMARY

In 1882, the electrical engineering discipline emerged in the United States from the science of physics and an era of self-taught tinkering to help make the twentieth century “an Amer- ican Century.” Since that time, electrical engineering profes-sionals have been at the forefront or have played a substantial role in most of the world’s major scientific discoveries and re-search breakthroughs. The rapid growth of the profession in the

United States has brought this nation to a dominant position in the discovery, innovation, and worldwide deployment of tech-nology. This progress continues all around the world and as the twenty-first century is entered the pace of technological inno-vation will continue to increase rapidly. Globalization will havea profound effect upon how and where technological innova- tions occur and will continue to be a driving force in making this century one of unprecedented opportunity. Educational in-stitutions in the United States play a seminal role not only in fundamental research, but also in developing a substantial por-tion of the world’s technical professionals. As educators in the United States develop new curricula and innovative pedagog- ical methods, they must be cognizant of where aspiring pro- fessionals will come from and where graduating professionals will be deployed. Current data predicts that the worldwide en- gineering workforce will be largely Asian in the next genera- tion. Newly industrialized countries in the Pacific Rim and other Asian countries are making long-term commitments to increasetheir engineering workforce [13]. To maintain a leadership posi- tion as the world’s educator and developer of engineering pro-fessionals, and to continue to grow in that position, American educators must continue to adapt the curricula not only to ac- commodate technological evolution, but also to prepare aspiring engineers to function in a dramatically changing cultural envi-ronment. They must also seek more effective and efficient ped-agogical methods to ensure that educators can meet the broader demands of the educational community.

The authors assert that *a degree that lives at the intersection
of science and engineering must be developed to ensure that new generations of engineers are able to thrive in a professional en-vironment of rapid technological and cultural change.* There al-ready exists tremendous dependency on computing, and the role that computers and computer-related disciplines play in nearly every aspect of engineering will continue to grow at an acceler-ated

pace. On that basis, the authors believe that *a combined de- gree in electrical and computer engineering provides the scope that undergraduates will ultimately need to be effective in this new world.* The model curriculum proposed in this paper ef- fectively merges the disciplines of mathematics, science, engi- neering, and computing. It also addresses the growing need for exposing aspiring engineers to the human, cultural, and profes-sional aspects of their emerging careers.

Some of the potential risks associated with the widespread proliferation of undergraduate specialization were also identi- fied and discussed. *A curriculum that attempts to optimize the conflicting attributes of generality and specialization will have the strongest appeal.* The authors also briefly describe how some of today's innovations and advancements might provide limitless potential for improving the efficiency, effectiveness, and quality of contemporary teaching methods. The realization of those benefits will require significant investment. Educa- tional institutions have played a foundational role in nearly every aspect of technological advancement and have been instrumental in providing unprecedented opportunity for the global community. It is indeed appropriate for the beneficiaries of the work of the educational community to collaborate with educational institutions to exploit the value of new technology

for the benefit of improving the technology of education because graduates of 2003 to 2013 are being prepared for employment until 2053 to 2063.

REFERENCES

J. D. Ryder and D. G. Fink, *Engineering and Electronics*. New York: IEEE, 1984.

L. E. Grinter, "Report on evaluation of engineering education (1952–1955)," *J. Eng. Educ.*, vol. 4, no. 1, pp. 25–63, 1955.

C. J. Baldwin, C. R. Cahn, J. W. Forman, H. Lehmann, and C. R. Wis- chmeyer, "A model undergraduate electrical engineering curriculum," *IEEE Trans. Educ.*, vol. E-22, pp. 63–75, May 1979.

V. R. Vemuri, "Computer science and engineering curricula," *IEEE Trans. Educ.*, vol. 36, pp. 108–110, Feb. 1993.

Model Curricula for Computing (2003). [Online]. Available: http://www.computer.org/education/cc2001/index.htm

J. A. Orr and B. A. Eisenstein, "Summary of innovations in electrical engineering curricula," *IEEE Trans. Educ.*, vol. 37, pp. 131–135, May 1994.

P. Merton, C. Clark, J. Richardson, and J. Froyd, "Engineering cur- ricular change across the foundation coalition: Potential lessons from qualitative research," *Proc. ASEE/IEEE Frontiers in Educ. Conf.*, pp. S1D8–S1D9, 2001.

D. L. Trautman, "Where are the frontiers in education?," *IEEE Trans. Educ.*, vol. E-20, pp. 138–140, Aug. 1977.

B. Schroder. (2003). *Implementing an Integrated Engineering Cur- riculum* [Online] Available: http://www2.latech.edu/~schroder/

R. M. Felder, L. E. Bernold, E. E. Burniston, J. E. Gastineau, and J.

B. O'Neal, "An integrated first-year engineering curriculum at North Carolina State University," *Proc. ASEE/IEEE Frontiers in Educ. Conf.*, pp. 4d48–4d4.11, 1995.

M. A. Soderstand, "The new electrical and computer engineering cur- ricula at University of California-Davis," *IEEE Trans. Educ.*, vol. 37, pp. 136–146, May 1994.

IEEE Computer Society/ACM Task Force. (2003). *Model Curricula for Computing* [Online]. Available: http://www.computer.org/educa- tion/cc2001/index.htm

F. A. Kulacki and E. R. Krueger. Trends in engineering educa- tion—An international perspective. presented at Proc. Int. Conf. Engineering Educ. [Online]. Available: http://www.ineer.org/Events/ ICEE1998/ICEE/Index.htm

N. C. Mickleborough and D. G. Wareham, "Motivational aspects associ- ated with learning in engineering," in *Proc. AEESEAP/FEISEAP/IACEE Int. Conf. Engineering Educ.*, 1993, pp. 67–72.

M. Baker. (2003) Global Wireless Education Consortium. [Online] Available: http://www.gwec.org/acro/gwec.pdf

Department of Electrical and Computer Engineering, Worcester Poly- technic Institute. (2003). [Online]. Available: http://www.ece.wpi.edu/

R. Hira, "Undergraduate engineering education curriculum and educa- tional research," presented at the Int. Symp. Technology Soc., Princeton Univ., Princeton, NJ, June 1996.

D. Moore and F. Berry, "Industrial sponsored design projects addressed by student design teams," *J. Engineering Educ.*, vol. 90, no. 1, pp. 69–73, Jan. 2001.

A. K. Ditcher, "Effective teaching and learning in higher education, with particular reference to the undergraduate education of professional en- gineers," *Internal J. Engineering Educ.*, vol. 17, no. 1, pp. 24–29, 2001.

D. Millard. (2003) Director of the Academy of Electronic Media Labo- ratory at RPI. [Online]. Available: http://www.academy.rpi.edu/

A. F. Johnson, "A design partnership: Distance education involving stu- dents and industry in a growing network," *Proc. North Midwest Sec- tion Meeting of ASEE*, Oct. 9–11, 1997.

F. Kaderali, G. Steinkamp, and B. Cubaleska, "Studying electrical engi- neering in the virtual university," *Internal J. Engineering Educ.*, vol. 17, no. 2, pp. 119–130, 2001.

Indiana Academic. (2003) Honors Diploma Requirements (Example). [Online]. Available: http://www.bsu.edu/burris/academics/highschool/iahonors.html

Indiana Department of Education. (2003) Foreign Languages. [On- line]. Available:

http://www.doe.state.in.us/standards/standards2000_ lang.html
Educational Resources Information Center. (2003) National K-12 Foreign Language Recourse Center. [Online]. Available: http://www. educ.iastate.edu/nflrc/

Baylor Engineering. (2003) Electrical and Computer Engineering. [On- line]. Available: http://ecswww.baylor.edu/ecs/engineering/eng.htm
Berkeley College of Engineering. (2003) Electrical and Computer En- gineering. [Online]. Available: http://www.coe.berkeley.edu/academics/eecs.html
Electrical and Computer Engineering (2003). [Online]. Available: http://www.ece.cmu.edu/undergrad/