
Transformational Paradigm for Engineering and Engineering Technology Education

Enrique Barbieri
Professor & Chair
Department of Engineering Technology
University of Houston
ebarbieri@uh.edu

William Fitzgibbon
Professor & Dean
College of Technology
University of Houston
fitz@uh.edu

Abstract

The knowledge explosion in science, technology, engineering & mathematics (STEM) over the past decades is unquestionably overwhelming. It is important that those involved in STEM quickly adapt. Life-long learning has taken a do-or-die slant, as technological breakthroughs turn obsolete within only a few years of their inception. Medical and law degree curricula became more “professional” and require a “pre-degree” status to be considered for admission. However, the traditional engineering degree plan is essentially the same as that of the mid 20th Century. Legislation in some states places additional pressure on baccalaureate degrees by questioning the need for anything above 120 credit hours. The result is (i) fewer engineering-specific courses; (ii) courses that heavily emphasize theory; and (iii) a subsequent reduction in hands-on, laboratory oriented, experiential learning. Engineering Technology curricula are designed to have experiential learning as the educational backbone. This forces a reduction in mathematical and scientific depth that is compensated by a richness of laboratory courses in almost one-to-one proportion to lecture courses, and which emphasize the application of engineering. The main challenges to establish and maintain experiential learning include (i) availability of slots in the curricula for laboratory courses; (ii) availability of funding for lab equipment and maintenance; (iii) space constraints exacerbated by the ongoing conversion of education laboratory space to graduate research space; and (iv) availability of dedicated faculty for instruction and preparation of labs that are modern, project-based, inquisitive, and synchronized with the lectures. We examine the factors that have prevented Engineering Schools & Colleges in the United States from following the medical or law models and advocate that Engineering Technology programs can play an important role in a new educational paradigm for Engineering Education. The model that we propose is based upon the thinking behind the Conceive, Design, Implement, Operate (CDIOTM <http://www.cdio.org/>) initiative.

Introduction

The United States has always placed a high value on higher education and the benefits that society accrues from an educated populace. We have been the beneficiaries of a steady stream of scientific and technological innovations [1]. In an address delivered to the 2004 Summit on Engineering Education in 2004, Charles Vest, President of the National Academy of Engineering and President of the Massachusetts Institute of Technology heralds the 21st Century as the “most exciting in human history for science and engineering”. The knowledge explosion in science, technology, engineering & mathematics (STEM) over the past decades is unquestionably overwhelming. Indeed in the last 40 years we have witnessed technological advances in virtually every imaginable field that defy our belief and remind us of feats first seen in the 1960s science fiction movies. The advent of the transistor and subsequent Moore’s Law, photonics, the digital computer and Internet, the space program, wireless communication, bio/nano-technology applications, medicine and genetic engineering are examples of incredible advances over the last 50 or so years. It is tantalizing to speculate what technological and scientific breakthroughs need to happen in the next 50 years because of the energy, environmental, transportation, health, and food requirements placed by a continuously increasing population.

B.T. Wright [2] has noted that we see a doubling of scientific knowledge every ten years. The knowledge explosion has been accompanied by a shortening of the development period and product-to-market cycle. Technological breakthroughs turn obsolete within only a few years of their inception. However there is deep concern about erosion of an educated workforce needed to sustain a position of scientific and technological leadership in the global economy. After secondary school, fewer US students pursue careers in science and engineering than in other countries. Approximately 6% of our undergraduate students study engineering. This places us second from the bottom in a ranking of industrialized countries. In European countries engineering students comprise about 12% of undergraduate enrollment. In Asia the percentage can be much higher, 20% in Singapore and 40% in China. Approximately one third of US students switch majors before graduation [1]. Older technologies are becoming obsolete at an accelerated rate and life long learning is becoming not only a path towards career advancement, but also a necessity for economic survival. If the knowledge explosion presents unprecedented challenges, opportunities are also unprecedented for educators in the STEM disciplines.

If the United States is to remain economically competitive, engineering educators as well as those involved in the broader spectrum of STEM education must respond to the knowledge explosion and the need to increase our technological workforce. Despite these unprecedented pressures, engineering education at most US institutions still follows a traditional model that dates back to the middle of the 20th Century. Although some engineering colleges notably those at Cornell, Ohio State and Minnesota have experimented with lengthened curricula of five years, students continue to struggle to complete an eight

semester (four year) degree plan that was put in place in the 1950s. Currently, about 60 credit hours of the degree plan are dedicated to core courses in mathematics, natural and social sciences, humanities, and writing. This squeezes engineering education into roughly 2 to 2 ½ years. Although both professional accreditation and the knowledge explosion justify an expansion of the degree plans, legislation in many states places additional pressure on baccalaureate degree plans by questioning the need for anything above 120 semester credit hours. Moreover engineering courses emphasize theoretical content reflecting a postwar embrace of science by engineering programs. The combined effect of all this has been: (i) there are fewer engineering-specific courses; (ii) engineering courses are highly theoretical and emphasize scientific analysis and mathematical modeling and (iii) there has been a subsequent reduction in hands-on, laboratory oriented, experiential learning and courses delving into engineering design (synthesis as opposed to analysis) and engineering operations have been deemphasized and relegated to perhaps one or two courses in the curriculum [3].

Many feel that the transition from applications to fundamental science in engineering education has been unfortunate and that experiential learning should form the backbone of engineering education. It is important that engineering education reflect what engineers actually do in practice and the practice of engineering requires synthesis as much as it does analysis [3, 4]. Questions concerning the proper balance between science, engineering science, and design are not new to engineering educators and have been debated for decades. Indeed one can say that over the years, engineering education has been the subject of more reports, studies, and discussions than any other branch of professional education [5]. In addition to the dominant issue of achieving an appropriate balance between theoretical and practical education, there have been discussions concerning the proper length of engineering education, the weak preparation of incoming students, competencies of engineering students in oral and written communication and teamwork and the nontechnical education of engineering students in the social sciences and humanities.

This position article proposes an educational model that to our knowledge has not been discussed in an open forum. The model utilizes existing resources in many universities, and recommends that Engineering Technology programs could fulfill pre-engineering requirements and even become pre-engineering degrees similar to a pre-med or pre-law degree. We discuss only the US model. It would be interesting to compare with other models, for example the European, although it must be recognized that European engineering programs offer both flavors – theoretical and applied, without degree name changes, and also that the European model is undergoing a restructuring phase following the European Bologna Agreement of 1999 leading to a B.S. and M.S. format similar to what prevails in the US [6].

The article is presented as follows: Section II provides a cursory overview of the development of Engineering and Engineering Technology Programs in the United States; Section III places Engineering Technology and Engineering in the context of the Engineering profession and the Conceive, Design, Implement and Operate (CDIO) framework; Section IV

discusses professional and first engineering degrees; Section V presents the position of this article; and Section VI concludes with suggestions for possible follow-up steps.

Historical Overview

Formal engineering education can be traced back to the establishment of Napoleon's Grande Ecole Polytechnique in France in 1794. In the United States engineering education also has a military antecedent with the founding of the US Military Academy at West Point in the early 19th Century. Rensselaer Polytechnic Institute founded in 1824 was the first non-military engineering school. However, most engineers of the early 19th Century learned their profession through an apprenticeship with little formal schooling. With the Morrill Act of 1862 and the concomitant opening of land grant institutions, engineering education began to shift from the shop floor to the classroom. Engineering curricula through the 19th and early 20th Centuries retained much of the flavor of an apprenticeship including a large number of shop and laboratory courses with little emphasis on scientific theory or mathematical analysis [3, 5, 7].

In the 1920's engineering education began to change. This transition was driven by a couple of factors. Emigrating European engineering professors with an academic tradition that had an emphasis on science and mathematics demonstrated the practical utility of mathematics in areas such as fluid mechanics, the vibration and dynamics of machinery, the strength of materials and the stress analysis on pavements dams and other structures [5]. The emergence of new technologies in electrical and chemical fields required an understanding of basic science and mathematics. Thomas Edison, despite his constituent attempts to portray himself as a trial and error inventor maintained one of the finest scientific libraries in the United States and made a practice of staffing his laboratory with European personnel holding doctoral degrees. The design and construction of the alternating current generators at Niagara Falls required an expertise in physics and mathematics found in the European but not the United States engineering community.

In the aftermath of World War II engineering colleges embraced science as a major part of the engineering core. The emergence of new military technologies such as radar and atomic weaponry, and new fields such as nuclear energy, telecommunications, materials science and computer science accelerated the emphasis on mathematics, physics, and engineering science. In 1955, the American Society for Engineering Education issued a seminal report on the Evaluation of Engineering Education [8], which in common parlance has become known as the Grinter Report named after L.E. Grinter, former Dean of Engineering of the University of Florida who chaired the committee that produced it. The Grinter Report, which became the foundation for program accreditation standards in engineering called for a heightened emphasis on science and mathematics. The movement to include more science and mathematics in engineering curricula was further enhanced by the successful launching of Sputnik and the perception that the US lagged behind the Soviet Union in technical capability. The heightened attention given to science, analysis and modeling resulted in a

reduction on the practical, hands on components of the curriculum. A much smaller part of the curriculum dealt with the design of engineering equipment, operations and mechanical drawing. The Federal government began to fund basic research (as opposed to applied research) and the nature of the engineering professorate began to change from individuals with extensive experience as practicing engineers to research scientist with PhD's having little or no industrial experience [3, 5, 7]. An exquisite historical perspective of becoming an engineer in Europe during the 1950s and 60s is given in [21], which places high value on the development of practical skills based on solid foundations.

Many of today's educators in engineering technology feel that in addition to articulating engineering accreditation standards, the Grinter Report and the deliberations that followed had a major impact on the emergence of baccalaureate engineering technology programs. In its preliminary form the report proposed a bifurcated engineering curriculum with a professional-scientific and professional-general tracks [7]. Although discussion of this bifurcation was omitted from the final report, a later article by Grinter is unequivocal about the intent to propose both research/scientific and more programmatic tracks in engineering disciplines [9].

As would most certainly be expected, the history of engineering technology programs is thoroughly intertwined with the history of engineering programs. However, engineering technology programs as we now know them are a much more recent phenomenon. Mechanical engineering programs initiated at land grant institutions such as Purdue, Texas A&M and Penn State evolved to the engineering technology programs found at those institutions today. The American industrial revolution spawned many technical institutes having the purpose of educating what could be called engineering technologists. Some of these institutions like the Massachusetts Institute became preminent. Others such as the Ohio Mechanics Institute have been incorporated into universities and some have disappeared. Schools like the Cogswell Polytechnic Institute produced engineering technologists for decades before they began to distinguish graduates with titles and degrees [7]. Other technology programs including those at the University of Houston, Southern Polytechnic State University and the Oregon Institute of Technology had their genesis in federally funded war training programs and veterans' readjustment programs during and immediately following World War II.

Many of these postwar programs were subsequently incorporated into two-year Associate's Degree programs. The University of Houston offered the first Associate of Applied Science degree in the late 1940's. Demand by both employers and students to include more training led to four-year baccalaureate degrees. In 1951, the University of Houston experimented by offering a path forward from its Associate of Applied Science (the University of Houston was the first to the AAS degree as well) by offering a Bachelor of Applied Science degree. Although the BAS was soon to be discontinued the effort to provide an academic path forward from the Associates degree did not die. H.E. McCallick headed a broadly

constituted committee with individuals from both engineering and engineering technology programs that produced an extensive report that eventually resulted in guidelines for baccalaureate technology programs in 1964. The first three programs reviewed in chronological order under these guidelines were located at Brigham Young University, Purdue University and the University of Houston.

Today, two-year programs in engineering technology are almost exclusively the province of the community college systems that have proliferated across the US states and other countries in the last fifty years. These programs typically are closely focused on local industry needs, have a local funding base and are frequently updated as a result of industry needs. They have the dual mandate of preparing technicians for immediate entry to the workforce and preparing individuals for forward articulation into baccalaureate programs in technology and engineering. Almost two hundred different institutions offer close to five hundred ABET accredited associate degree programs.

Well over 100 different institutions offer over three hundred TAC of ABET accredited baccalaureate programs graduating close to four thousand technologists annually. A wide spectrum of disciplines is represented but the bulk of the programs are in the electrical/electronic, mechanical, and manufacturing fields. There is a mandate of industrial experience for engineering technology faculty that although desired does not normally exist in engineering programs. Engineering technology programs continue to be more pragmatic and “hands on” than engineering and feature heavy emphasis on laboratory experience, practice-oriented lectures, and experiential learning. Graduates of technology programs find employment across the technological spectrum but are more apt to be found in applications, implementation, and production/process oriented positions as well as in technical customer support and sales. Engineering technologists frequently oversee and communicate with the technical workforce. The type of student that finds “home” in engineering technology programs shares a characteristic interest and ability in finding out how things work by tinkering. On the other hand, the type of student that is successful in engineering programs shares a characteristic interest and ability in finding out why things work by delving into mathematical and scientific abstractions. Each educational track has the right ingredients for each type of student to progress and be successful whether in more practical or more theoretical tasks. Both types are very much sought after; and there is agreement that engineering technology programs of the 21st Century produce the equivalent of the engineer of the early to mid 20th Century in terms of what industry needs and expects. Perhaps this state of affairs is also caused in part by a decline in Industry’s willingness to sponsor what could possibly be several months of training programs for recent hires. More frequently, Industry expects Universities to provide the environment and opportunities for that training. The reality is however that 2 ½ years of engineering courses is not sufficient to do justice to both theory and practice. A fairly recent account of the historical development of engineering, engineering technology, and accreditation boards in the context of the importance of laboratory instruction is given in [20].

Engineering Technology (ET) & CDIO

According to the Engineering Technology Division of the American Society for Engineering Education (ASEE), Engineering Technology is defined as follows:

Engineering Technology (ET) is the profession in which knowledge of the applied mathematical and natural sciences gained by higher education, experience, and practice is devoted to the application of engineering principles and the implementation of technological advances for the benefit of humanity. Engineering Technology education for the professional focuses primarily on analyzing, applying, implementing and improving existing and emerging technologies and is aimed at preparing graduates for the practice of engineering that is close to the product improvement, manufacturing, and engineering operational functions.

By definition then, ET degree plans are designed to have experiential learning as the educational backbone. The reduction in mathematical and scientific depth is compensated by a richness of laboratory courses that are almost in one-to-one proportion to lecture courses. Furthermore, lecture courses tend to emphasize the application of techniques in solving engineering problems. Table 1 below shows the approximate core lecture/lab breakdown at the University of Houston, College of Technology's Department of Engineering Technology illustrating one example of the extent of experiential learning that is typically embedded in ET programs.

Table 1 Approximate Breakdown of ET Core Lecture/Lab Courses at UH TAC/ABET accredited B.S. degrees in Computer ET (CET), Electrical Power ET (EPET), and Mechanical ET (MET). (53 Semester Credit Hours)

	Lecture	Lab	Capstone
CET	13 courses (54%)	9 courses (38%)	2 courses (8%)
EPET	13 courses (57%)	9 courses (39%)	1 course (4%)
MET	11 courses (52%)	8 courses (38%)	2 courses (10%)

The quality of ET programs can be measured using a variety of metrics on faculty, facilities, staff, student, and other programmatic support. Professional accreditation certainly confirms the achievement of a standard according to these metrics. In post-2000, the ABET criteria further allow the definition of program focus and direction that align with the Institution's. In preparation for the 2007-08 re-affirmation of SACS accreditation, the University of

Houston embraced a Quality Enhancement Plan (QEP) centered on undergraduate research experiences. Quite fitting to this QEP, the ET programs at the University of Houston accredited by the TAC of ABET have for years placed a strong emphasis and financial support on their senior year capstone courses. The reasoning is that program quality has been successfully demonstrated by student accomplishments and that the capstone courses provide a fertile setting for students to be creative and for collection of program assessment materials. Recent and highly meritorious ET faculty, staff, and student achievements at the University of Houston placed the department 8th in the number of BS degrees awarded in 2005-06 from a list of 50 schools; 9th in 2006-07; and 17th out of 47 departments and centers at UH in FY07 external funding with over \$1M in annual research expenditures for 3 consecutive years.

Accreditation concerns, pressure from industry advisory boards and prospective employers, and feedback from students continue to put pressure on Engineering and Engineering Technology departments alike to invest in revamping their programs' laboratory experiences. The critical importance of laboratories in engineering instruction has been reaffirmed over the years by the ASEE in several reports [20, and references [11], [12], and [13] therein]. The main challenges to establishing or increasing and then maintaining experiential learning are not trivial and include (i) availability of slots in the curricula to add additional laboratory courses; (ii) availability of funding for lab equipment and maintenance; (iii) space constraints as most lab space may have been converted to graduate research space; and (iv) availability of dedicated faculty for instruction and for preparation of labs that are modern, project-based, inquisitive, and synchronized with the lectures.

As early as in the 1962 ASEE report "Characteristics of Excellence in Engineering Technology Education" [10] the engineering field was "... *viewed as a continuum extending from the craftsman to the engineer.*" By treating "engineering" as in "engineering profession", the relative placement of engineering (E) and engineering technology (ET) programs can be more clearly depicted in the *Conceive, Design, Implement & Operate* (CDIOTM) [11, 12] **horizontal** spectrum shown in Figure 1.

It is widely understood that E curricula tend to prepare its graduates to accept responsibilities closer to "design" and even "conceive" functions. By necessity, E students are required to undertake mathematics courses beyond calculus, science courses that are based on differential and integral calculus, and core engineering courses that demonstrate the utilization of math and science in system level design situations. By contrast, ET curricula prepare its graduates to accept responsibilities closer to the "implement" and even "operate" functions, which require a different focus, different interest, and indeed a different skill-set from abstractions and complex mathematical manipulations. Currently, a small percentage of E graduates continue on with further studies leading to MS and PhD degrees to move into purely "conceive" positions. On the other hand, only a small percentage of ET graduates start with job functions at the purely "operate" level. It is safe to assert that the majority of E and ET graduates after a few years in the field gravitate toward the middle section of the spectrum where design, analysis, re-design, system integration and technology

implementation meet. Moreover, these graduates become indistinguishable from each other as they are both involved in “functional engineering” tasks.

Conceive	Design	Implement	Operate
Conceptualization & Abstract Design Set, Define, & Model System Goals, Function, & Architecture		Engineering Practice Operations Management	
Engineering & Scientific Research Multi-disciplinary and Multi-objective Design		Applied Research & Functional Engineering Design/Optimize Operations & Training	
			
System & Hierarchical Design Utilization of Knowledge in Design Design Under Constraints		Application Specific Analysis & Re-design Implementation Design System Lifecycle, Improvement, Evolution, & Support	
Research & Development of Future Technologies Design Process, Phases, & Approaches Development Project Management Ensure Reachable Goals		Application & Deployment of Current & Emerging Technologies Hardware Manufacturing – Software Implementation Hardware/Software Integration Test, Verify, Validate, & Certify Disposal & Life-End Issues	

Figure 1 Conceive, Design, Implement, Operate Engineering Spectrum

One example of the last assertion is given in [22]. The authors provide survey evidence from participants representing a broad range of industries, and find there are no significant differences in the roles and responsibilities between manufacturing engineers and manufacturing technologists, and that there are no significant differences in the technologies utilized on the job. In fact, although 34.5% of the participants reported an E-based education, 64% reported engineering as their job function. Participants also identified the top 6 most important areas where engineers and technologists would be regularly involved. Five of these areas were found to be shared by these professionals. They are all involved in “functional engineering” tasks.

Motivated by the discussion presented in the previous sections, we began to ponder on the following question: could an educational model be constructed whereby ET programs are utilized as a pre-requisite to E programs or even built as a pre-engineering degree? Before addressing this and other related questions however, it is worth to briefly examine the debate on “first professional engineering degrees” as well as to describe some existing approaches found at various Universities that essentially deal with increasing the length of study for an engineering degree.

Professional Engineering and First Engineering Degree

As described in [13], the US Department of Education recognizes “First Professional Degrees” having a study cycle of at least 2 years of pre-professional preparation, followed by a number of years of professional preparation, for a total length of 6 years. For example, students pursuing degrees in Law, Medicine, and Pharmacy undertake cycles of 4/3, 4/4, and 2/4, respectively. The complete list of unique fields awarding first professional degrees not offered at the undergraduate level is Chiropractic, Dentistry, Law, Medicine (Allopathic, including surgery), Optometry, Osteopathy, Pharmacy, Podiatry, Theology (ordination qualifications), and Veterinary Medicine [14]. An important distinction is also made that these are first degrees and not graduate research degrees.

It is not surprising that engineering degrees requiring 4 years total, with no pre-engineering preparation, are deemed to fall short of the US DoE definition of first professional degree. Both the Institute of Electrical and Electronic Engineers (IEEE) and the American Society of Mechanical Engineers (ASME) have supported a B.S. in Engineering as a first professional degree, indicating also the importance of life-long learning and that many engineers seek additional formal education. In the IEEE September 2007 print edition of “The Institute” [17], readers were polled with the following question: “Should the first professional degree in engineering be at the Bachelor or Master level?” The result of the survey indicated that the vast majority of the respondents believe that the B.S. degree is enough. Despite heated opposition, there have been proposals for appending a number of years to the baccalaureate engineering degree, resulting in BS/Master and BS/Doctorate combinations for a First Professional Engineering Degree [13, 15]. The American Society of Civil Engineers (ASCE) has advocated for almost 10 years that the master's be the first professional degree for Civil Engineering practice [16]. On the contrary, the American Society of Mechanical Engineers (ASME) Board of Governors released a statement in June 2008 that opposes the requirement of BS plus 30 credits beyond the First Professional Degree for PE registration – a requirement that the National Council of Examiners for Engineers and Surveyors (NCEES) supports. The opposition is joined by the American Institute of Chemical Engineers (AIChE) and the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE). There appears to be a worldwide movement to requiring a previous degree in order to confer a professional degree. In engineering, the master's degree seems to solve this problem. Since graduate programs in engineering are very well established, it is natural that these have been recommended as first professional engineering degrees. One may ask why the idea hasn't already fully caught on and implemented. Possible reasons are (i) society in general seems to be willing to accept a much higher cost for a solution to a medical, business, or legal crisis than an engineering one probably because of the personal nature and cost of the crisis; and (ii) it is widely recognized that the engineering employment industry would have to step up and substantially raise starting salaries and benefits to compensate for the 50% increase in educational requirements and time-to-graduation. Recent data showed a 30% increase in engineering master's degrees awarded between 1998-99 and 2004-05. However, enrollment dropped by almost 10% between 2003 and 2005. Hence, a decline in degrees awarded is expected for the next several years [21].

Medical and law degree plans have adapted and over the years have become more “professional”, and require a “pre-degree” status to even be considered for admission. What has stopped US Engineering Colleges & Schools from following suit and expanding their curricula? The diplôme d'ingénieur awarded in France is generally obtained after 5 or 6 years of studies. Most if not all Latin American countries follow European models and award engineering degrees after 5 or 6 years of studies that include mandated industry co-op experiences. Although the five year plans of Cornell, Ohio State, and Minnesota were quickly dropped, many reports focus on a debate of solutions that include (i) adding one year to the 4-year standard; (ii) requiring Professional Engineering (PE) status; or (iii) defining a master or even doctoral degree as the first professional Engineering degree. Opposing views include (i) such solutions do not address the core issue of substandard experiential learning; (ii) many engineering disciplines do not require PE status; and (iii) graduate courses are more theoretical and do not necessarily increase hands-on and technology know-how.

Nevertheless, BS/Master and other degree combinations have become almost standard offerings in many Institutions in the US. As discussed earlier, the current 4-year engineering plan clearly presents a great deal of constraints and challenges to engineering departments such as (i) severe time constraints and lack of resources (human and facilities) to cover breadth and depth of both theoretical and practical engineering subjects, (ii) pressure to develop softer skills such as communication and life-long learning; and (iii) how to instill professional ethics in a sea of safety, sustainability, environmental, and design costs issues. Because of these constraints, many schools either have in place or are designing 5 year programs that offer (i) BS/MS, BS/ME, or BS/MBA combinations; (ii) dual degrees such as BS/BE in closely related disciplines; or (iii) fifth year extensions into a specific discipline specialization. For example, NYU has a five year BS/BE program that combines a Bachelor of Engineering degree with a Bachelor of Science in Mathematics; the University of California San Diego has five year programs leading to Bachelor's and Master's Degrees in Computer Engineering; and Rutgers offers a five-year, dual-degree program in bioenvironmental engineering offered by the School of Engineering in cooperation with the School of Environmental and Biological Sciences (SEBS).

We would like to conclude this section with an interesting observation. The U.S. Office of Personnel Management [19] requires for all professional engineering positions that either the curriculum be ABET accredited as a professional engineering curriculum, and include differential and integral calculus in five of seven engineering science or physics areas, or that the candidate have a combination of college-level education and practical experience. The adequacy of such background must be demonstrated for example by Professional registration, or by passing the FE exam, or by completing certain specific courses or related curricula, and having at least 1 year of work experience under guidance or supervision. The reason this is relevant is that in these requirements there is no mention of graduate studies, but rather, work or practical experience is the underlying requirement.

The next and final section describes an educational model option that could the requirements of both the Department of Education for a first professional degree, and the U.S. Office of Personnel Management for professional engineering positions; it would maintain the graduate degrees' emphasis on theoretical and research endeavors; and it would utilize existing TAC of ABET accredited programs in engineering technology available in over 100 Universities in the US.

A New Paradigm

The new paradigm of this position article is based upon the utilization of TAC of ABET Accredited programs in Engineering Technology available in over 100 US Universities. Two main options emerge from the discussion presented in previous sections.

Option 1: Two-Year Pre-Engineering Requirement

When properly designed and executed, the first two years of accredited, 4-year B.S. degrees in ET disciplines can serve as the pre-engineering requirement for engineering-bound students. We submit then that the template for a 2-year, University-level, pre-engineering program is already in place in at least 100 US Universities. If executed, it is envisioned that a new first professional engineering degree can be defined whereby:

1. All engineering-bound students would first complete 2 years of a TAC/ABET 4-year engineering technology program in an appropriate discipline.
2. With proper advising and mentoring, those students interested and skilled to follow the more abstract (Conceive-Design) side of engineering would transfer to a College or School of Engineering and complete a BS-E degree in 2 or 3 or 4 additional years. If 4 years, then the Department of Education definition of a first professional degree would be satisfied.
3. On the other hand, those students interested and skilled to follow the more applied (Implement-Operate) side of engineering would opt to complete a BS-ET degree in 2 additional years.

Several benefits can be listed:

1. Total enrollment in E and in ET would increase as a result of proper advising and mentoring in the early stages of the student's university experience affecting freshman and sophomore retention.
2. Retention rates at the upper level of both E and ET would also increase.
3. Avoid duplication of efforts and resource expenses for equipping and maintaining laboratories needed in the first 2 years.

Engineering departments can better focus on advanced/graduate level education with better utilization of professorial staff.

Option 2: Pre-Engineering Degree Requirement

It is also conceivable that Engineering Colleges would consider becoming in the future professional schools much like medical and law schools requiring a 4-year baccalaureate pre-degree for admission. As in the pre-med option, the pre-engineering degree could be in any field, but would include certain requirements of mathematics, sciences, engineering, and technology. A B.S. degree in an ET field would surely be a most fitting pre-engineering degree. An apparent benefit of either option discussed above is that Colleges and Schools of Engineering would be able to devote more of their resources to graduate engineering programs leaving freshman and sophomore level engineering classes to ET programs.

Many or most of the discussion items in this section depend heavily on whether or not the ET program operates within a College or School of Engineering. A search in the U.S. News and World Report site www.usnews.com lists 307 US Institutions with 2- and 4-year Engineering Technology/Technician degree programs. An informal poll of the Engineering Technology Division list-serv etd-1@listproc.tamu.edu conducted during April 2008, and targeting the questions to Chairs and Directors of 4-year ET programs and departments resulted in 33 responses with about 50% of these operating within Colleges or Schools of Engineering. 32 of 33 respondents indicated that most or all their programs are TAC of ABET accredited. Also, approximately 50% of the respondents have a graduate program leading to a Master of Science or Master of Technology degree. Establishing graduate ET degrees presented a great deal of controversy in the early 80s and the real issues and the non-issues were summarized in [19]. Graduate programs would be an important item in any formal discussion of the educational model presented in this article.

Conclusions

In this article, we have taken the position that TAC of ABET Accredited Engineering Technology programs that currently thrive in over 100 US Universities could be utilized to address some of the concerns that the 21st Century engineering profession and education are facing. The new model has not been previously discussed in an open forum and provides an alternative that would meet the requirements of both the Department of Education for a first professional degree in terms of length of study, and the U.S. Office of Personnel Management for professional engineering positions in terms of experiential learning. The model is also an alternative to proposals recommending that master's degrees be defined as the first professional engineering degree. We advocate that engineering graduate degrees maintain an emphasis on theoretical and research endeavors. Potential follow up discussion items with educators and industry advisors that would shed light and bring other points of view into this educational model include in no particular order:

1. What are the academic requirements of a pre-engineering degree?
2. Standardization of breadth and depth of fundamental engineering courses such as electric circuits and statics/dynamics.
3. Development of 2-year templates for E and ET programs [23-25].
4. Pros and cons of 2-, 3-, or 4-year models for the BS-E degree and accreditation concerns.
5. Maintenance and staffing of laboratories.
6. Capstone experiences and Undergraduate Research in E and in ET.
7. Graduate programs and opportunities in E and in ET.
8. Faculty credentials, joint appointments, retention, and Promotion and Tenure.
9. Options for Universities that do not have ET programs.
10. Challenges and opportunities for Community Colleges.
11. How to maximize the involvement of Industry and Professional Organization leaders.

A website is being maintained that posts articles and comments in an effort to stimulate broad participation from the community. The reader is encouraged to visit the site and participate in the discussion:

<http://www.tech.uh.edu/faculty/barbieri/E%20and%20ET%20Project.htm>

Acknowledgements and Final Remarks

The authors would like to thank the anonymous reviewers and many other colleagues for their various comments that helped improve the accuracy and quality of the paper. Finally, we include the following remarks to be further discussed or developed in future opportunities:

- The US Department of Education classification of First Professional Degree is being revised.
- Rochester Institute of Technology has proposed an undeclared ME/MET program for a group of students during their first year that would lead to the ME or MET programs in the second year without loss of credits.
- During the course of writing the final version of this article, we became aware of Oregon Institute of Technology's approach to locate Mechanical Engineering and Mechanical Engineering Technology programs in the same department while sharing a common first 2 years [26].

References

- [1] Committee on Prospering in the Global Economy of the 21st Century, "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future", National Academy Press, Washington, DC. 2007.

- [2] B.T. Wright, "Knowledge Management", Presentation at the Industry/University/Government Roundtable on Enhancing Engineering Education, Iowa State University, Ames, May 1999.
- [3] P.C. Wankat, R. M. Felder, K.A. Smith, and F.S. Oreovicz, "The Scholarship of Teaching and Learning in Engineering", Chapter 11, *Disciplinary Styles in the Scholarship of Teaching and Learning: Exploring the Common Ground*, AAHE/Carnegie Foundation for the Advancement of Teaching, Washington. DC, 2002.
- [4] B.V. Koen, "Definition of the Engineering Method", American Society for Engineering Education, Washington, 1985
- [5] B.E. Seeley, "Patterns in the History of Engineering Education Reform: A Brief Essay" *Educating The Engineer of 2020*, National Academies Press, Washington, DC, 2005, 114-130.
- [6] "The Future of European Universities" www.europaeum.org/content/view/58/65/
- [7] G. William Troxler, "Introduction", *Engineering Technology: An ASEE History* (M.T. O'Hair general editor), Glencoe/McGraw Hill, Westerville, Ohio, 1995, 1-7
- [8] L.E. Grinter et al, "Report on the Evaluation of Engineering Education", *Journal of Engineering Education*, 1955 (September), 25-60
- [9] L.E. Grinter, *Engineering and Engineering Technology Education*, *Journal of Engineering Technology*, 1984 (March), 6-8. Also presented at the University of Houston, College of Technology.
- [10] "Characteristics of Excellence in Engineering Technology Education", Final Report ASEE 1962, www.engtech.org/AdditonalLinksFiles/TheCharacteristicsofExcellence.pdf
- [11] E.F. Crawley, J. Malmqvist, S. Ostlund, and D. Brodeur, "Rethinking Engineering Education: The CDIO Approach", Springer, Berlin 2007.
- [12] CDIO Site <http://www.cdio.org/>
- [13] P. Dorato, "The First Professional Degree: Master of Engineering?", in "Advances in Statistical Control, Algebraic System Theory and Dynamic Systems Characteristics", edited by C-H. Won, C. B. Schrader, and A. N. Michel, Published by Birkhauser 2008, pp.313-318.
- [14] Department of Education: Characteristics of First Professional Studies. Online at <http://www.ed.gov/about/offices/list/ous/international/usnei/us/edlite-structure-us.html>
- [15] B. Friedland and P. Dorato, "A Case for the Doctor of Engineering as a First Professional Degree", 1987 ASEE Journal of Engineering Education, Vol. 77, pp. 707-713.
- [16] Jeffrey S. Russell, Brewer Stouffer and Stuart G. Walesh, "The First Professional Degree: A Historic Opportunity", *ASCE J. Professional Issues in Engineering Education and Practice*, Volume 126, Issue 2, pp. 54-63 (April 2000)
- [17] The IEEE Institute's Poll: "What Should Be the First Professional Degree in Engineering?" www.moshekam.org/commentary/files/WhatShouldBetheFirstProfessionalDegreeinEngineering.pdf
- [18] U.S. Office of Personnel Management: Professional Engineering Positions Requirements. Online www.opm.gov/qualifications/SEC-IV/B/GS0800/0800.htm

- [19] L. J. Wolf, "Graduate Education in Engineering Technology: What are the Real Issues," 1982 ASEE Journal of Engineering Education, vol.72, p.809.
- [20] L. D. Feisel and A. J. Rosa, "The Role of the Laboratory in Undergraduate Engineering Education", ASEE Journal of Engineering Education, January 2005, Vol. 94, No. 1, pp.121-130.
- [21] Databytes Column, "Many Master's", ASEE Prism, January 2007, pp.22-23
- [22] R. R. Smith, M. P. Jones, and R. N. Callahan, "Manufacturing Engineer - Manufacturing Technologist: Exploring the Similarities and Differences", in the Technology Interface Journal, Vol.9, No.1, online at <http://technologyinterface.nmsu.edu/Fall08/>
- [23] E. Barbieri, R. Pascali, M. Ramos, W. Fitzgibbon, "A 2-year common template for Mechanical Engineering and Mechanical Engineering Technology", Ac 2009-1955, Proceedings of the ASEE, Austin Tx, 2009, ASME Division.
- [24] E. Barbieri, W. Shireen, F. Attarzadeh, M. Ramos, W. Fitzgibbon, "A 2-year common template for Electrical/Computer Engineering and Electrical/Computer Engineering Technology", Ac 2009-1998, Proceedings of the ASEE, Austin Tx, 2009, IEEE Division.
- [25] E. Barbieri, W. Shireen, F. Attarzadeh, R. Pascali, M. Ramos, W. Fitzgibbon, "CDIO-based 2-year common templates for ECE/ECET and for ME/MET", Ac 2009-2026, Proceedings of the ASEE, Austin Tx, 2009, ETD Division.
- [26] T. Brower, "Can Engineering and Engineering Technology Programs Reside within the Same Department?", Proceedings of the 2006 ASEE Annual Conference and Exposition, June 18-21, Chicago, IL. (Paper online at www.asee.org)

Biography

ENRIQUE BARBIERI received his Ph.D. in Electrical Engineering from The Ohio State University in 1988. He was on the faculty of the Electrical Engineering Department (1988-96) and a tenured Associate Professor and Chair of the Electrical Engineering & Computer Science Department (1996-98) at Tulane University. In 2002 he joined the University of Houston as Professor & Chair of the Department of Engineering Technology. His research interests are in control systems and applications to electromechanical systems. He is a member of IEEE and ASEE and Chairs the Executive Council of the Texas Manufacturing Assistance Center.

WILLIAM FITZGIBBON, III earned his BA and PhD degrees from Vanderbilt University in 1968 and 1972 respectively. He is currently serving as Dean of the College of Technology of University of Houston and holds professorial rank in both the Department of Mathematics and the Department of Engineering Technology. He served as Chair of the Department of Mathematics, co-Head of the Department of Computer Science and President of the

University of Houston Faculty Senate. He has held faculty positions at the University of California, San Diego and the University of Bordeaux I and the University of Bordeaux II as well as a research position at Argonne National Laboratory in Illinois. He has well over 130 research articles plus numerous articles, reviews, and reports and has lectured extensively in North America, Europe and Asia.