On B.S.E and B.S.ET for the Engineering Profession

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Abstract

An educational model for ABET-accredited baccalaureate programs in Engineering (E) and in Engineering Technology (ET) is proposed whereby all students inclined to pursue an engineering career would first complete two years of a 4-year ET program. By the end of the sophomore year, those students interested and skilled enough to follow a more theoretical or conceive-and-design side of an engineering career would go on to complete a degree in perhaps two to four additional years in a department that offered E degrees. The 4-year option would satisfy the Department of Education definition of a 6-year first professional degree. On the other hand, those students interested and skilled enough to follow a more applied or implement-and-operate side of an engineering career would opt to complete a degree in two additional years in a department that offered ET degrees. The model offers clearly defined options to students interested in an industry-based engineering profession two to four years after graduation where conceive-, design-, implement- and operate-tasks are assigned. If adopted, the model will result in several benefits including: (1) improved program marketing; (2) increased enrollment and retention rates; and (3) improved human and facility resource utilization at both undergraduate and graduate E and ET education.

1. Introduction

A healthy supply of articles dealing with engineering (E) and engineering technology (ET) education is readily found in conference proceedings and journal venues. It is widely accepted that since the Grinter Report of 1955,1 E programs in the U.S. have grown to be more theoretical, leaving fewer curricular opportunities for the student to experience the practice of engineering, especially during the freshman and sophomore years. A glaring exception is perhaps Olin College of Engineer-

ing, which opened in fall 2002 to an inaugural freshman class that follows a hands-on, interdisciplinary and rigorous curriculum that is claimed to better reflect actual engineering practice. In general, though the 4-year window leading to a B.S. in an engineering specialty has been densely packed with technical and non-technical courses, a de-emphasis of laboratory instruction, an increase in lecture hours and theoretical content, and, paradoxically, a decrease in total hours required to obtain the degree while the pressure continues to mount to also have business, project management, ethics, communication, and other “soft” skill development courses.

Over the years, baccalaureate ET programs accredited by the Technology Accreditation Commission of ABET have been established in over 120 institutions of higher education across the U.S. that maintain a laboratory-rich and practical philosophy of engineering education while reducing the mathematics and science depth that is required of E courses. Much has been written about E programs and how they should adapt, address the non-negligible freshman and sophomore attrition rates, and meet the NAE Grand Challenges. Likewise, much has been written about ET programs, their role, identity, and relevance challenges. Inevitably, much is also written to compare and contrast E and ET programs many times in an effort to clarify to our constituents and to each other the proverbial question “What is ET?”

Despite all the literature, conference meetings, and debates, there continues to be a remarkable amount of miscommunication with the media, parents, counselors, employers, and prospective students. This miscommunication is accompanied by a subtle and damaging image problem that results in misguided advice that is imparted to students of both the E and the ET degree programs. The result is that students get confused. Many abruptly leave E before they get a chance to experience engineering. Some who transfer to ET may do so and feel that they failed; yet they eventually discover that the practical aspects offered by ET were what they were looking for all along. They then graduate and lead a rewarding career in engineering. Likewise, faculty, academic counselors and industry recruiters get con-
fused, and many are misinformed. Many do not know that there are E and ET programs, cannot tell them apart or believe that an ET degree is (or should be) a 2-year junior college degree. And many do not know or realize that both E and ET graduates serve critical purposes in industry and the global economy.

This brief invited article is based on the recent publications\(^2\) that provide a historical overview of engineering and engineering technology, introduce the placement of these degree programs within a conceive, design, implement, operate or CDIO framework, discuss various viewpoints on first professional engineering degrees, propose an educational model that effectively utilizes engineering and engineering technology resources, and present 2-year common curriculum templates for Electrical/Computer Engineering (ECE) and Electrical/Computer Engineering Technology (ECET), and for Mechanical Engineering (ME) and Mechanical ET (MET) programs. The templates assume a full-time course of study in four semesters during which the student selects to either complete a BS in Engineering Technology in two additional years, or transfer to an Engineering degree plan which may be two, three, or four years long. Both plans are assumed to be constructed so as to be ABET accredited by the appropriate commission. The templates are offered as a starting point to encourage further discussion.

This article then welcomes the opportunity to offer a summary of a vision that shares available E and ET programs, so that the university-led educational system can more efficiently couple to the industry-based employment system. These two systems should ideally strive to work together so that program marketing, student recruiting, retention, and graduation, utilization of faculty resources, quality and staffing of facilities, professional accreditation, and career placement become components of a machine that ultimately ensures increased student engagement followed by professional success in an engineering career. In the remainder of this article, “engineering” will normally refer to the profession three to five years after graduating with an E or an ET degree.

2. Placing E and ET within CDIO

To the authors’ knowledge, placing E and ET curricula philosophies within the Conceive, Design, Implement, and Operate (CDIO\(^{TM}\) http://www.cdio.org/) professional engineering spectrum is a new perspective\(^2\). It is widely understood that E’s 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’s 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 with further studies leading to a Ph.D. degree and move into purely “conceive” positions. Similarly, only a small percentage of ET graduates start or stay 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 engineering spectrum, where design, re-design, system integration, performance analysis, translational research, and technology implementation meet. Moreover, studies have been done that show these graduates become indistinguishable from each other as they are both involved in “functional engineering” tasks.

The quality of undergraduate E and ET programs can be measured using a variety of metrics on faculty, facilities, staff, student, and other programmatic support. Professional accreditation by ABET certainly confirms the achievement of a standard according to these metrics. Post-2000, the ABET criteria further allow institutions to define the program focus and direction within certain guidelines. In preparation for the 2007-08 reaffirmation of SACS accreditation, the University of Houston embraced a Quality Enhancement Plan (QEP) centered on undergraduate research experiences\(^8\). Quite fitting to this QEP, the ET programs at the University of Houston and many other institutions 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.

Accreditation concerns, pressure from industry advisory boards and prospective employers, and feedback from students continue to put pressure on E and ET 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\(^9\), and references therein. Well-equipped laboratories are critical in the implement-operate side of engineering tasks—hence on ET programs. Some design-intensive engineering fields, for example control engineering, also depend heavily on having laboratory-oriented opportunities to test or verify design techniques. The main challenges to establishing or increasing and then maintaining experiential learning via laboratories are not trivial and include (i) space availability in the curriculum to add additional laboratory courses; (ii) funding availability 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.

3. Educational Model

The educational model offered here for discussion is based upon the utilization of TAC of ABET-accredited programs in Engineering Technology available in more than 120 U.S. universities. Again, the reader is reminded that in this article “engineering” refers to the profession three to five years after graduating with an E or an ET degree. Two main options may emerge:

3.1 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 templates for a 2-year, university-level, pre-engineering program are already in place in at least 120 U.S. universities. If executed, it is envisioned that by the second year, students will have had enough opportunities to test their skills and develop interests to be well positioned to make an educated career choice early enough, which will benefit not just the student but the entire engineering profession.

Similar ideas have been proposed for a common freshman experience and a common sophomore experience for Electrical Engineering and Electrical ET majors at Temple University to have an impact on retention and to facilitate student transfers between the two programs10. Similar ideas have been implemented in the Manufacturing and Mechanical Engineering & Technology Department at the Oregon Institute of Technology11. To the authors’ knowledge, OIT’s implementation is the only one of its kind in the U.S.

In essence the idea is that:
1. All engineering-bound students would first complete two 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 department, college or school of engineering and complete an E degree in two to four additional years; if four years, then the Department of Education definition of a first professional degree would be satisfied. See [2] and references therein for a discussion about first professional engineering degrees, including the role of graduate degrees.
3. Those students interested and skilled enough to follow a more applied (Implement-Operate) side of engineering would opt to complete a B.S.-ET degree in two additional years.

Several benefits can be listed:
1. Total enrollment in E and in ET would increase as a result of unambiguous marketing to high schools and junior colleges, and 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 because students will be placed on a degree path that better fits their interests and skills.
3. As a result of the above, graduation rates will improve, with a corresponding increase in the supply of qualified individuals entering the engineering profession.
4. Avoid duplication of efforts and resource expenses for equipping, maintaining, and staffing laboratories needed in the first two years.
5. Departments offering E degrees can better focus on advanced/graduate level education with better utilization of professorial staff.

3.2 Common First Two Years

The common first two years would necessarily increase the math/science requirements for ET majors, and increase the lab exposure and applications requirements for E majors. The following modifications are deemed necessary for ET and E programs3,5:

1. ET programs:
   a. Include one math course per semester, starting with Calculus I.
   b. Physics and engineering courses such as circuit analysis, statics/dynamics need to be calculus-based.
   c. Include a seminar course per semester designed to keep the students engaged throughout the curriculum. These would play a significant role in reinforcing the CDIO philosophy, in advising/retenition and career planning, in clarifying the differences in the academics of E and ET programs, and in helping the students identify their strengths and interests. The sequence gives opportunities to cover topics in innovation, creativity and design, IP, the globalization of knowledge, engineering ethics, and economics all in the context of real case-based scenarios. These are left unspecified to also allow flexibility for individual programs to establish special emphases or to introduce a first course in design if so desired.
2. E programs:
   a. Include one engineering course per semester, each with a three-hour laboratory.
   b. Include a seminar course per semester as described above.
3.3 Option 2: Pre-Engineering Degree Requirement

It is also conceivable that engineering colleges/schools would consider becoming professional schools, much like medical and law schools requiring a 4-year baccalaureate pre-degree for admission. As in the pre-med option, for example, the pre-engineering degree could be in any field, but would include certain requirements of mathematics, science, engineering, and technology. A B.S. degree in an ET field would surely be a most fitting pre-degree. The Department of Education definition of a first professional degree would be satisfied.

4. An E and ET Forum

Under a 2010-11 award by FIPSE, the Fund for the Improvement of Postsecondary Education of the Department of Education (P116V090007), we take the next steps to formulate critical questions and answers on E and ET education by key constituents in academia, industry, professional organizations, and accreditation commissions in a formal forum at the University of Houston on April 29–May 1, 2010. A preliminary report based on the panel recommendations will be distributed for discussion during summer 2010. A subset of the panel will reconvene in early fall 2010, and a final report will be produced and disseminated widely.

Discussion topics will include: accreditation; measurable impacts on undergraduate and graduate E and ET education; adoption of a new educational paradigm in more than 120 institutions that have E and ET programs; articulation agreements for those institutions lacking ET programs; challenges and opportunities for community colleges; involvement of industry and professional organization leaders; academic requirements of a pre-engineering degree; pros and cons of 2-, 3-, or 4-year models for the E degree; retaining a first professional degree; resource savings in maintenance and staffing of laboratories; capstone experiences and undergraduate research; graduate programs; faculty credentials, joint appointments, retention, and promotion and tenure; enrollment, attrition, and retention management; graduation-rate increase; professorial focus on Ph.D.-level education; and others. The impact of this project is both on undergraduate and graduate E and ET education affecting most if not all institutions of higher education in the U.S.12

5. Conclusions

Engineering (E) and Engineering Technology (ET) programs can be correctly placed along the Conceive, Design, Implement, & Operate (CDIO) framework. In order to offer both the theory and the practice of engineering, hence affecting student recruiting and retention in engineering fields, the article discusses how to utilize common resources available in engineering and engineering technology programs. A forum at the University of Houston in April 29–May 1, 2010 brings together a group of faculty and administrators from engineering and engineering technology to further discuss ways in which these two established programs can work together for the benefit of each other and the engineering profession. The focus of these and future discussions should be on the engineering profession: 3-5 years after graduation. Therefore, it is quite fitting to conclude by quoting the following observation13 “The degree is Engineering Technology. The career is engineering.”

References
11. T. Brower, “Can Engineering and Engineering Technology Programs Reside within the Same Department?,” Proceedings of the 2006 ASEE Annual Conference and Exposition, Chicago, IL.

12. Project Website (Note: If viewing in Internet Explorer v8, choose “Compatibility Mode” in “Tools”) http://faculty.tech.uh.edu/?q=content/e-and-et-forum.


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