AC 2009-2026: CDIO-BASED TWO-YEAR COMMON TEMPLATES FOR ECE/ECET AND FOR ME/MET

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CDIO-Based 2-Year Common Templates for ECE/ECET and for ME/MET

Abstract

A new educational paradigm was recently proposed by the authors that effectively places Engineering and Engineering Technology programs within the **C**onceive, **D**esign, **I**mplement, and **O**perate (CDIO^{TM} http://www.cdio.org/) professional engineering spectrum. The new model advocates that a TAC/ABET accredited, 4-year B.S. degree in ET disciplines is a logical, viable, and in fact a key component in the student's path to entering the engineering profession and in earning degrees from Engineering Departments. If the model is adopted, it is envisioned that a new first professional engineering degree can be constructed whereby: (1) All engineering-bound students would first complete 2 years of an ET program – such as Computer, Electrical, or Mechanical ET; (2) With proper advising and mentoring, those students interested and skilled to follow the more **C**onceive-**D**esign side of engineering would transfer to a Department, College or School of Engineering and complete an Engineering degree in 2, 3 or 4 additional years; if 4 years, then the Department of Education definition of a first professional degree would be satisfied; and (3) Those students interested and skilled to follow the more applied **I**mplement-**O**perate side of engineering would opt to complete the BS in ET degree in 2 additional years. Several benefits include: (1) Enrollment increase in both Engineering and in ET as a result of proper advising and mentoring in the early stages of the student's university experience; (2) Retention rate increase at the upper level; (3) Avoidance of duplication efforts and resource expenses for staffing, equipping and maintaining laboratories needed in the first 2 years; and (4) Engineering departments can better focus on advanced/graduate level education with better utilization of professorial staff.

This article examines 2-year common curriculum templates for Electrical/Computer ET and Electrical/Computer Engineering, and Mechanical Engineering and Mechanical ET programs based on CDIO, and summarizes preliminary assessment results of the proposed educational model collected from industry participants. The templates assume a full-time course of study in 4 semesters after which the student selects to either complete a BS in Engineering Technology in 2 additional years, or transfer to an Engineering degree plan which may be 2-, 3-, or 4-years long. Both plans are assumed to be constructed so as to be ABET Accredited by the appropriate Commission. The individual templates are being presented in separate articles at this conference through the corresponding IEEE and ASME Divisions. The templates are offered as a starting point to encourage further discussion.

Introduction

There is no question that the knowledge explosion in science, technology, engineering & mathematics (STEM) over the past decades has exceeded anyone's foresight. 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 Electrical Engineering field has morphed with incredible advances made possible by the advent of the transistor and subsequent Moore's Law, the digital computer and Internet, wireless communication, and applications to every other scientific field. What will the recently announced *memristor* bring in the next decade? It is also tantalizing to speculate what technological and scientific breakthroughs in various scientific and engineering fields need to happen in the next 50 years because of the energy, environmental, transportation, health, and food requirements placed by a continuously increasing population. If history serves us well, it is critically important that engineering education be one step ahead of the curve to prepare the next generation of engineering professionals, researchers, and academicians.

The National Academy of Engineering has unveiled the 14 Grand Challenges that are awaiting engineering solutions www.engineeringchallenges.org/ in energy, infrastructure & the environment, health & medicine, security, and in technology and tools for research and for instruction & learning. A common thread in the 14 Grand Challenges lies in ensuring that the educational system equips engineers with the skills needed to tackle these grand technical problems. At the recent March 2-3, 2009 NAE Summit in Durham, North Carolina, several of these challenges were discussed, and the imperative of having strong math and scientific foundations, a knowledge of business and entrepreneurship, an awareness of the global environment, and soft-skills development in engineering education was made clear. However, in the authors' opinion, it has also become clear that out of the typical 4-year plan, the roughly 2 ½ years worth of engineering courses are not sufficient to do justice to both the theory and the practice of engineering, let alone all the other skills required of the 21st Century Engineer.

References[1-20] discuss some of the major developments in the world order, in the engineering field, and in the educational structure of engineering and engineering technology of the last century leading to the present situation. Despite the obvious pressures to meet the demands of a technologically advanced and industrialized nation, engineering education at virtually all US institutions still follows a traditional model that dates back to the middle of the 20th Century designed to emphasize theoretical content reflecting a postwar embrace of science by engineering programs. A glaring exception is perhaps Olin College, which opened in fall 2002 to an inaugural freshman class www.olin.edu/about_olin/olin_history.asp after creating and testing "an innovative curriculum that infused a rigorous engineering education with business and entrepreneurship as well as the arts, humanities and social sciences. They developed a hands-on, interdisciplinary approach that better reflects actual engineering practice." Many feel that the transition from engineering applications to fundamental engineering science has been unfortunate and that experiential learning should form the backbone of engineering education. As recent as January 2009, the article "Engineering Schools Prove Slow to Change" by P.

Basken in The Chronicle of Higher Education points to the latest report by the Carnegie Foundation for the Advancement of Teaching, which indicates the strong emphasis on theory vs. practice in engineering education discourages many students and does not expose graduates to sufficient real-world problems.

Solutions to this dilemma may not be simple as legislation in many states places additional pressure on baccalaureate degree plans by questioning the need for anything above 120 semester credit hours. In engineering and engineering technology, both professional accreditation and STEM knowledge explosion justify additional credits hours beyond 120 in the degree plans. But, how many more credit hours are need to cover the practical content of engineering? 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[21]. The current situation is that (i) there are fewer engineering-specific courses squeezed in the 4-year plan; (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.

Another important topic of relevance to this article is the definition of a First Professional Degree (FPD). The US Department of Education recognizes a FPD 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 at least 6 years. For example, students pursuing degrees in Law, Medicine, and Pharmacy undertake cycles of 4/3, 4/4, and 2/4, respectively. An important distinction is also made in that, although the recognized titles are “doctor” or “master”, these are first degrees and not graduate research degrees such as PhD or MS[15]. B.S. in Engineering degrees requiring 4 years total, with no pre-engineering preparation, are deemed to fall short of the US DoE definition of FPD. 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 an FPD, indicating also the importance of life-long learning and that many engineers seek additional formal education.

Since graduate programs in engineering are very well established, it is natural that these have been recommended as FPD[14, 16, 18, 20]. The American Society of Civil Engineers (ASCE) has advocated for almost 10 years that the master's be the FPD for Civil Engineering practice[17]. 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 FPD for PE registration – a requirement that the National Council of Examiners for Engineers and Surveyors (NCEES) supports. The American Institute of Chemical Engineers (AICHE) and the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) join the opposition. One may ask why the idea of setting the MS in engineering as the FPD hasn’t 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[22].

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? 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/MS, BS/ME, BS/MBA and other degree combinations have become almost standard offerings in many Institutions in the US.

Finally, the U.S. Office of Personnel Management[20] 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 to this discussion is that in these requirements there is no mention of graduate studies, but rather, work or practical experience is the underlying requirement.

This article examines 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 that may begin to provide a long-term answer to several of the issues listed above. The templates assume a full-time course of study in 4 semesters after which the student selects to either complete a BS in Engineering Technology in 2 additional years, or transfer to an Engineering degree plan which may be 2-, 3-, or 4-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. We conclude with a summary of preliminary assessment results of the proposed educational model collected from industry participants. A much more comprehensive survey is underway. The individual templates are being presented via separate articles to the IEEE and ASME divisions, respectively.

Conceive, Design, Implement and Operate (CDIO)

It is widely understood that Engineering (E) curricula tend to prepare its graduates to accept responsibilities closer to “design” and even “conceive” functions. By necessity, engineering 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, Engineering Technology (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.

The E and ET curriculum philosophies can be easily placed within the **C**onceive, **D**esign, **I**mplement, and **O**perate (CDIO™ http://www.cdio.org/) professional engineering spectrum depicted in Figure 1. To the authors’ knowledge, this is a new perspective.

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

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 engineering spectrum where design, analysis, re-design, system integration, performance analysis, and technology implementation meet. Moreover, these graduates become indistinguishable from each other as they are both involved in “functional engineering” tasks.

One example of the last assertion is given in[23]. 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.

An example of the de-emphasis of laboratory instruction, the increase in lecture hours, and decrease in total hours required to obtain an engineering degree is given in[24]. The author describes a 60-year period in the evolution of undergraduate and graduate aeronautics and aerospace degree programs at the Polytechnic Institute of Brooklyn. Of much relevance to this article is Figure 2 below (original Figure 5 in reference[24], reproduced here with written permission from the author), as it illustrates a trend that, although particular to Aeronautics & Aerospace Engineering programs in one Institution, it probably can be assumed to be valid for all other engineering fields across the US.

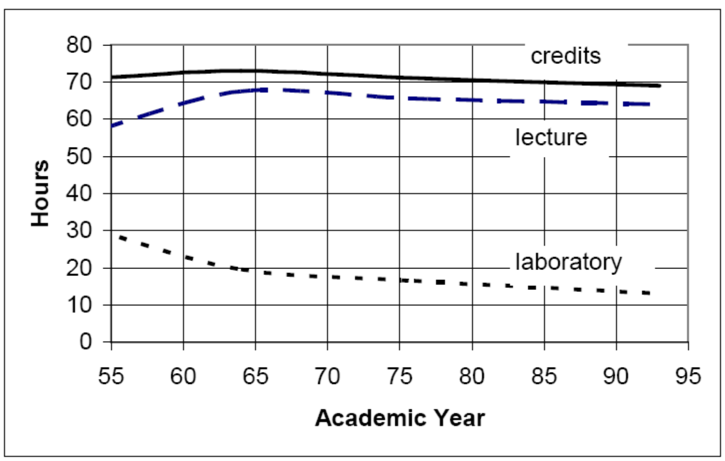

Figure 5 Polytechnic aero program requirements in laboratory and lecture hours for combined junior and senior years as a function of academic year

Figure 2 "Polytechnic aero program requirements in laboratory and lecture hours for combined junior and senior years as a function of academic year" (original Figure 5 in reference[24], reproduced here with written permission from the author).

Engineering Technology (ET)

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%)

Many of today's educators in engineering technology feel that in addition to articulating engineering accreditation standards, the Grinter Report[9, 10] 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. 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[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[21], and references[11, 12, 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.

This article builds on a recently proposed educational model[1] based on the CDIO™ framework. The new paradigm is based upon the utilization of TAC of ABET Accredited programs in Engineering Technology available in over 100 US Universities. Two main options emerge:

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 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 (**C**onceive-**D**esign) side of engineering would transfer to a Department, College or School of Engineering and complete an engineering (BS, MS, Doctoral) 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 (**I**mplement-**O**perate) 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.
4. 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.

A 2-year Template for ECE and ECET Programs

Based on our experience, on conversations with other faculty members, and on an examination of a representative sample of online degree plans at various Institutions, we present in this section a generic 2-year template for students declaring ECE and ECET majors. The sample group of online plans that was examined is:

Purdue University BSCmpE
UT Austin Computer Engineering
University of Houston BSECE
Duke University BSECE
Virginia Tech BSEE
University of Florida BSCEN
University of California – Santa Barbara BSEE

The University of Florida includes one summer term as part of the freshman year, and the sample degree plan takes 10 terms to complete. The program at Virginia Tech has 19 credits (7 courses) in mathematics during the first two years. Some Institutions defer the Humanities and Social Science electives to the senior year in order to introduce as many technical courses as possible during the first two years. Most if not all have added some form of "freshman engineering experience" as an effort to increase/maintain interest and impact enrollment retention. Clearly, no template can accommodate the variety of plans; and both ET and E programs must reach compromises. We decided to focus on the technical requirements of typical first 2 years such as mathematics, physics, and electrical & computer engineering courses. In essence, the common 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 to be new for ET and E programs:

1. New for ET programs:
   a. Include one math course per semester, starting with Calculus I; College Algebra and pre-Calculus become necessary pre-requisites.
   b. Physics and circuit analysis courses need to be calculus-based
   c. Include a Seminar course per semester

2. New for E programs:
   a. Include a circuit analysis course per semester, each including a 3-hour laboratory
   b. Include a Seminar course per semester

Table 2. A 2-year Template for ECE and ECET Programs
Format: Course (a, b) where a=number of lecture hours; b=number of lab hours

Term 1	Term 2	Term 3	Term 4
MATH I (4, 0)	MATH II (4, 0)	MATH III (4, 0)	MATH IV (3, 0)
CIRCUITS I (3, 3)	CIRCUITS II (3, 3)	DIGITAL CKT (3, 3)	ELECTRONICS (3, 3)
ENGL I (3, 0)	ENGL II (3, 0)	COMP PGM (2, 3)	ELECTIVE
HUM-SS I (3, 0)	PHYS I (3, 3)	PHYS II (3, 3)	HUM-SS II (3, 0)
E & ET I	E & ET II	E & ET III	E & ET IV
16 HRS	**16 HRS**	**16 HRS**	**16 HRS**

- ❖ MATH I, II, III typically correspond to CALCULUS I, II, III, respectively. MATH III may also be a "Numerical Solutions" course dealing with engineering problem solving.
- ❖ MATH IV is a standard course in engineering mathematics covering fundamentals of applied differential equations, linear algebra (matrices, eigenvector problems), and Applications using Laplace and Fourier transforms. Some ET programs may elect to replace MATH IV with an ECET course so that ET-bound students can make the transition starting in the 4-th term.
- ❖ ENGL I and II, and HUM-SS I and II, are typical composition courses and humanities or social science electives, respectively.
- ❖ Circuits I and II, and Physics I and II are calculus-based.
- ❖ Computer Programming (CMP PGM) is a course on computer-based engineering problem solving.
- ❖ The courses E & ET I-IV could be designed to keep the students engaged throughout the curriculum. These would play a significant role in reinforcing the CDIO philosophy, in advising/retention 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 & 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 put special emphases or to introduce a first course in design if so desired.
- ❖ The Elective course in Term 4 would enable the students to begin a transition to either an ECET or ECE degree plan. A typical ECET approved course would be Microprocessor

Architecture (lecture and lab). Also, some ET programs may elect to replace MATH IV with an ECET course.

- ❖ We believe that ECET programs can be completed in 4 additional terms reaching the minimum of 124 hours as required by TAC/ABET. ECE departments would have to discuss/decide/design remaining 2, 3, or 4-year plans and associated degree distinctions (BS, MS, ME, Doctoral).

A 2-year Template for ME and MET Programs

The Mechanical Engineering discipline serves a very diverse occupational spectrum. ME and MET programs have various emphases in their curriculum in order to properly serve their constituencies - Solid Mechanics/Design, Thermal/Fluids, Controls/Mechatronics and Materials/Manufacturing are the most common. In devising a common freshman and sophomore years, the diversity of the concentrations creates a challenge. In the past, attempts have been made to standardize the freshman year[25]. This and many other implementations were aimed at remedying the high attrition rate for the students enrolled in engineering as well as giving the entering students a broad enough initial knowledge that would allow them to switch majors within the engineering field. We believe that the scope of these solutions is too wide. Instead, we propose to limit the scope by serving one discipline ME/MET. For example, 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 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].

When students are asked why they chose to pursue engineering, and in particular mechanical engineering, invariable they indicate an interest in "designing things, taking them apart and putting them back together". However, the typical freshman/sophomore years do not meet those aspirations, leading to disappointment, lack of participation in courses and eventual withdrawal from the engineering field. We believe that a series of courses applicable to the four concentrations mentioned above, that would address the students desires while efficiently delivering the basic knowledge required of an engineering professional, would help achieve the set goals. We advocate the principle used to teach lectures: "First tell them what you are going to tell them; then tell them; and finally tell them what you told them", to encompass entire programs. The students become familiarized with the field they will be working in, while acquiring much needed skills at the freshmen year; they will study various subjects in depth in the following years, and all the knowledge would be summarized and brought together in the senior year, during a capstone experience. The essence of engineering is to design and build systems. Voland, in his book "Engineering by Design" describes engineering as "An innovative and methodical application of scientific knowledge and technology to produce a device, system or process, which is intended to satisfy human need(s)". If one subscribes to the above definition, then every engineer has to be somewhat knowledgeable of manufacturing methods, of drafting (drawing) standards and programming techniques. We are proposing that these topics be covered in freshmen/sophomore level courses.

Manufacturing Methods Course

Manufacturing in the US has been continuously shrinking in the past decades, reaching historical lows (www.infowars.com/us-manufacturing-at-lowest-level-since-1948/). One reason for the decline can be attributed to the lack of awareness of graduating engineers of the challenges presented in manufacturing a particular product. The lack of manufacturing/materials courses in the higher education curricula is in stark contrast with entering students' desire to "put things together and take them apart". Our template includes a Materials and Processes (MAT & PROC) course. The goals of a freshmen course in Materials and Processes would not be to produce certified machinists (although that may fit well in some programs), but it would rather teach students how to calculate feed rates based on various tools and materials used for various machines (traditional and high speed) using scientific methods; how to select materials for various applications and using a tensile test; and even techniques used in reverse engineering products to analyze the designer's choices. A properly designed course, with an applied experience in a lab setting, should instill in the students' minds, the need to study subsequent areas in the upper-division courses such as heat transfer needed for faster operations of machines, controls to apply a time varying load in the tensile testing machine, operation of CNC machines, and CAD for manufacturing.

Engineering Graphics Course

Another element sought by entering freshmen is the usage of high-end technology. This is understandable in today's world of 24 hour connectivity, with IM and podcasting. A topic such as Engineering Graphics lends itself very well to addressing the thirst for leading edge computer applications. Today's MCAD (Mechanical Computer Aided Design) solid modeler can be used not only to generate designs and working drawings using established standards, but also can perform analysis, create animations and can export files used to generate rapid prototyped parts in a matter of hours. Giving a freshmen student the ability to design a part, find its weight from the CAD model, observe its deformed shape under given loads, and finally hold a rapid prototyped part in his/her hands in a matter of hours. This is an experience not easily forgotten!

Numerical Methods Course

Programming courses for mechanical engineers have evolved dramatically over the years, mimicking the advancing technologies. From Fortran to C or C++ in terms of structured programming, to data flow programming in software such as LabView. In LabView, students can readily program from simple mathematical and sorting operations, to advanced controllers in a graphical environment, easily customizable without the tremendous overhead of older languages.

In our survey of programs from information available online, the total hours required for a BS degree varied from as high as 137 to as low as 126. The current ABET criteria specifies a minimum of 124 semester hours for <u>ET</u> programs, with no specifics for <u>E</u> programs. Some Institutions defer the Humanities and Social Science electives to the senior year in order to introduce as many technical courses as possible during the first two years. If one assumes a somewhat uniform distribution of the semester credit hours over an undergraduate career spanning 8 semesters, the number of credits per semester will range between 15 and 18 hours. The proposed two-year template ranges between 65-68 credit hours and is given in Table 3.

Table 3. A 2-year Template for ME and MET Programs.
Format: Course (a, b) where a=number of lecture hours; b=number of lab hours

Term 1	Term 2	Term 3	Term 4
MATH I (4, 0)	MATH II (4, 0)	MATH III (4, 0)	THERMODYN I (3, 0)
ENGL I (3, 0)	ENGL II (3, 0)	HUM-SS I (3, 0)	HUM-SS II (3, 0)
CHEM (3, 3)	PHYS I (3, 3)	PHYS II (3, 3)	STRENGTH MAT (3, 3)
ENG GRAPH (2, 3)	NUM METH (2, 3)	STATICS (3, 0)	DYNAMICS (2, 3)
E & ET I	MAT & PROC (2, 3)	E & ET II	E & ET III
16-17 HRS	**17 HRS**	**16-17 HRS**	**16-17 HRS**

Again, no template can accommodate the variety of plans. The focus was placed on the technical requirements of typical first 2 years such as mathematics, physics, and mechanical engineering background courses. The common two years would necessarily increase the math/science requirements for ET majors, and increase the lab exposure and applications requirements for E majors:

- MATH I, II correspond to CALCULUS I, II, respectively. MATH III may be used for CALC III, or some schools might want to use it for a more applied Engineering Math.
- ENGL I and II, and HUM-SS I and II, are typical composition courses and humanities or social science electives, respectively.
- Physics I and II are calculus-based.
- The courses E & ET I-II could be designed to keep the students engaged throughout the curriculum. These would play a significant role in reinforcing the CDIO philosophy, in advising/retention 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 & 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 put emphasis in more manufacturing courses or to introduce a first course in design if so desired.
- E & ET III in Term 4 would enable the students to begin a transition to either an MET or ME degree plan.
- We advocate including a lab component in the Strength of Materials course to provide practical equivalents to lecture concepts such as yield point identification.
- Statics, Dynamics and Thermodynamics are standard engineering courses.
- We believe that MET programs can be completed in 4 additional terms reaching the minimum of 124 hours as required by TAC/ABET. ME departments would have to discuss/decide/design remaining 2, 3, or 4-year plans and associated degree distinctions (BS, MS, ME, Doctoral).

It may be argued that lower math requirements are a key differentiator between E and ET programs and that higher math & science requirements for all may attract a larger number of students to E. As discussed earlier, we believe the overall impact on retention for both programs would be positive due to proper advising and mentoring during the first two years. A good number of our ET students are transfers from E during their junior year! The intent here is to enable students to make an informed career decision much earlier and based on skills and interest which will benefit not just the student but the entire engineering profession.

Preliminary Assessment Results

In fall 2008, we administered a brief preliminary survey to industry professionals regarding the topic of a 2 year common curriculum for ECE and ECET programs. A total of 12 people completed the survey, ten of which had a degree in an engineering or engineering technology discipline. Ten of the respondents also had 11 or more years of industry experience. A summary of results is presented in Figure 3.

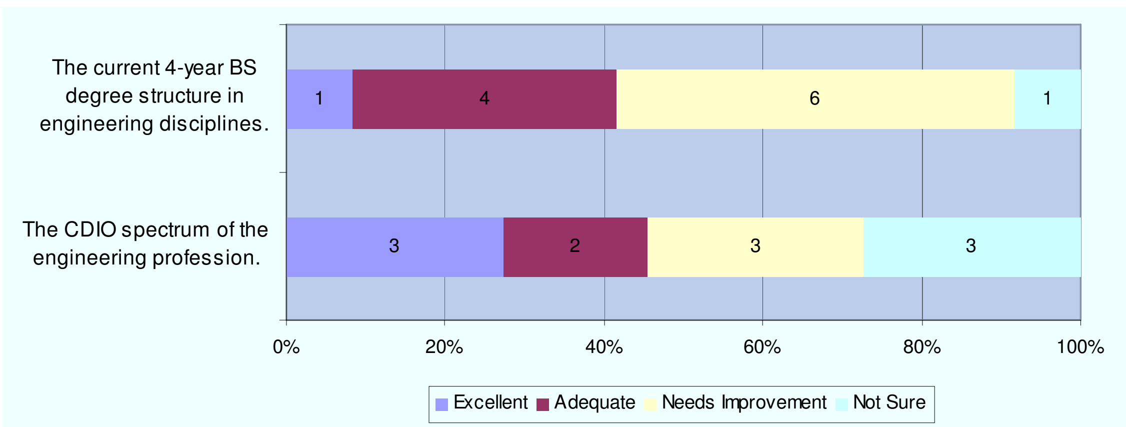

Figure 3. Industry Perception of Current Engineering Degree Structure

Six of the respondents felt the current standard 4-year B.S. degree structure in engineering disciplines needs improvement. Only one person thought that the current structure was "excellent." However, there was no consensus on whether the CDIO spectrum of the engineering profession was a viable alternative.

Figure 4 below shows the results from a second set of questions that asked industry professionals to reflect on the placement of engineering and engineering Technology graduates. A majority of respondents indicated that they understood the differences between engineering and engineering technology students. Most respondents also suggested that they take an active role in placing both types of students in industry positions. The survey participants were split regarding the utility of formal post-graduate studies for engineering graduates in industry. On the other hand, the majority of survey participants did not believe formal post-graduate studies were needed for engineering technology students to better function in industry.

While the survey was a useful exercise to gain some industry perspective on the issue of a common curriculum, the small number of participants limits the usefulness of the responses. The next step is to implement a more rigorous survey methodology to collect data from faculty around this topic. Toward this goal, we are working with the Director of Assessments and Accreditation Services (DAAS) for the College of Technology to construct a survey and sampling frame that will provide faculty insights regarding the common curriculum concept presented here.

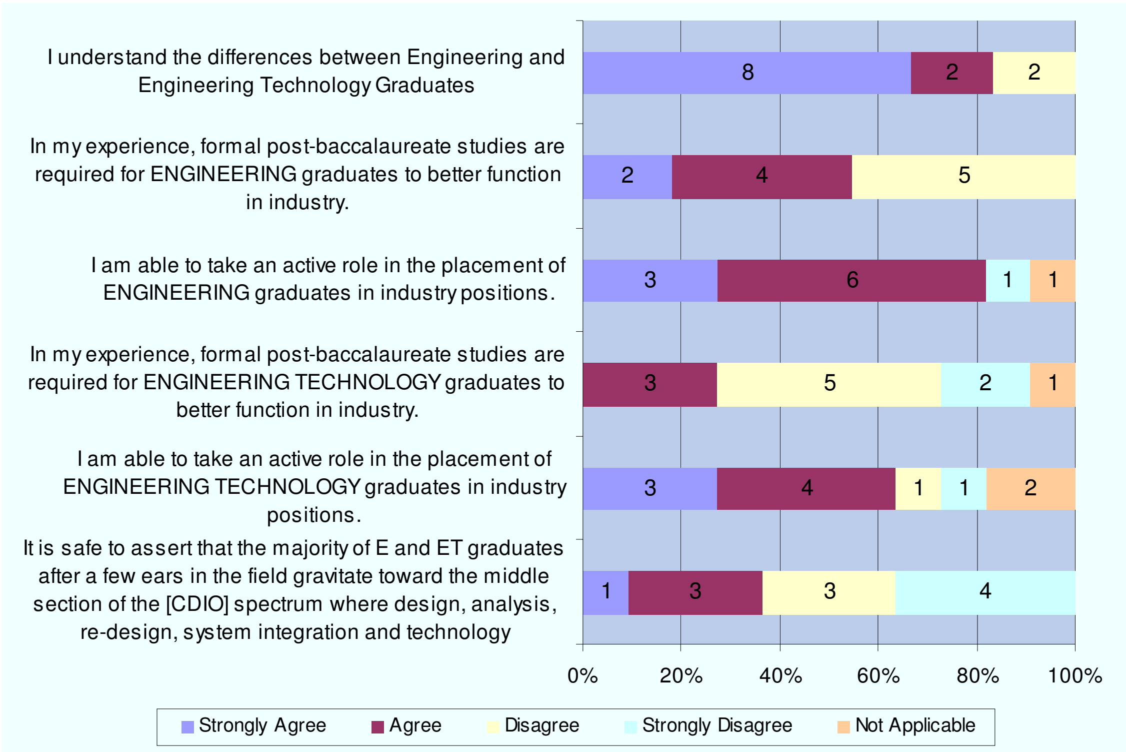

Figure 4. Examining Differences between E and ET Students in Industry

The initial population for the survey has been defined as those schools that are included as part of the ASEE Engineering and Engineering Technology College Profiles for 1998-2008. Since the survey relates specifically to the curricular structure of engineering technology relative to engineering, a subpopulation of schools that offer Engineering Technology was identified as the focus for the survey sample. From this subgroup, 26 universities and colleges were randomly selected to participate in the survey. Within each school, we have identified faculty who teach under the broad heading of Engineering Technology or who are listed as instructors in Mechanical, Computer, or Electrical Engineering Technology. The resulting faculty sample currently exceeds 300 people. Implementation of the survey will be carried out electronically with results and analysis complied by the DAAS for the college.

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 impacting student recruiting and retention in engineering fields, the article presents a 2-year common template for students majoring in

Electrical/Computer Engineering or in Electrical/Computer Engineering Technology. We find that E and ET programs need to reach a compromise where the first two years include more depth of mathematics and science for ET programs, and more experiential learning opportunities for E programs via laboratories every semester. Seminar-style courses are included to encourage advising and special topic instruction to reinforce the CDIO philosophy and assist students in identifying their strengths. The 4th semester includes an elective to allow students to begin their transition to an E or an ET degree plan. ET majors can complete their B.S. in 2 additional years. Engineering departments can design 2, 3 or 4 additional years of study and corresponding B.S., M.S., and Doctoral degree distinctions; if 4 years, then the Department of Education definition of First Professional Degree would be satisfied. Potential follow up discussion items include:

- What are the academic requirements of a pre-engineering degree?
- Standardization of breadth and depth of fundamental engineering courses such as electric circuits and statics/dynamics.
- Pros and cons of 2-, 3-, or 4-year models for the BS-E degree and accreditation concerns.
- Maintenance and staffing of laboratories.
- Joint Capstone experiences and Undergraduate Research in E and in ET.
- Graduate programs and opportunities in E and in ET.
- Faculty credentials, joint appointments, retention, and Promotion and Tenure.
- Options for Universities that do not have ET programs.
- Challenges and opportunities for Community Colleges.
- 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:
http://www.tech.uh.edu/faculty/barbieri/E%20and%20ET%20Project.htm

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