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An Analysis of Engineering Credits in ABET Accredited Engineering Management Programs

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Engineering Topic Credits for ABET Accredited Engineering Management Programs

ABSTRACT

The American Society for Engineering Education (ASEE) database on engineering programs and graduates indicates there are 23 programs in the United States classifying themselves as engineering management (EM). Of these 23 programs, only five are ABET accredited EM programs. Additionally, there are six ABET accredited EM programs not listed in the ASEE database. Overall, there are only 11 ABET accredited EM programs on a national basis (programs with management in the name). Although it is unclear why the majority of the EM programs do not pursue ABET accreditation, one possible explanation may be a lack of understanding on what curricular topic may or may not qualify as an engineering credit. Further complicating this question is how the program criteria of EM are fulfilled and how that course work relates to the engineering credit count. Especially problematic in the process of balancing these requirements and constraints is the limit of total program credits.

This paper provides a first step in exploring these issues by analyzing current ABET EM programs and documenting the allocation of engineering topic (ET) hours along with how they satisfy program criteria. The paper examines the allocation of credits and generalizes the approach employed by these programs to accomplish the required engineering credits and the program criteria. We found that there was a disparity in ET content in like courses; especially for the less technical topics. Also, programs that taught the courses within the department, in general were able to claim higher ET hours than those where the less technical topics were taught outside the department.

Introduction

Based on a range of influences such as the globalization of the manufacturing base, outsourcing of many technical services, efficiencies derived from advances in information technology (and the subsequent decrease in mid-management positions), and the shifting of the economy to a service-based orientation, technical organizations and engineering in general are experiencing a significant change in overall career characteristics and expectations. The nature of this change can be seen in this description of what a 21st century technical organization must be concerned with:[1]

(1) maintaining an agile, high quality, and profitable business base of products or services in an unstable and global economy,
(2) hiring, managing, and retaining a highly qualified and trained staff of engineers, scientists, technicians, and support personnel in a rapidly changing technological environment, and
(3) demonstrating a high level of innovation, entrepreneurship, and capability maturity usually with an ever increasing amount of government oversight and regulation.

One response to these global realties has been a significant growth of engineering management (EM) related topics and programs, especially at the graduate level. At the undergraduate level, there has also been growth in terms of related classes, minors, and certificates that are embedded within traditional degrees. However, the number of undergraduate EM programs has seen little growth. Currently, as shown in Table 1, the ABET website[2] lists eleven accredited undergraduate programs in the US and five internationally with the word "management" in the program name and only Clarkson University has received its initial accreditation in the US in the last five years. Only five use the term "engineering management" exclusively for the program name. A recent American Society for Engineering Education (ASEE) publication on domestic engineering programs lists 23 EM undergraduate programs, which also are summarized in Table 1.[3]

Table 1. ABET accredited and ASEE EM Related Programs

ABET Accredited EM Programs*	ASEE Listed EM Undergrad Programs
Domestic	University of Arizona
University of Arizona** (2003)	Arizona State University
Clarkson University*** (2009)	California State, Long Beach
University of Connecticut (1978)	California State, Northridge
Missouri University of Science and Technology ** (1979)	University of California – Santa Cruz
North Dakota State University (1971)	Christian Brothers University
Oklahoma State University (1936)	The College of New Jersey
University of the Pacific**(2003)	Colorado School of Mines
Rensselaer Polytechnic Institute (1978)	Gonzaga University
South Dakota School of Mines and Technology (1991)	Illinois Institute of Technology
Stevens Institute of Technology** (1990)	Mercer University
United States Military Academy** (1985)	Miami University
	Missouri University of Science and Tech.
International	University of North Carolina - Charlotte
Arab Academy for Science and Technology and Maritime Transport (2009)	University of the Pacific
	NYU Polytechnic School of Engineering
Istanbul Technical University (2009)	University of Portland
Kuwait University (2006)	Southern Methodist University
Universidad Autonoma de San Luis Potosi (2012)	St. Mary's University
University of Sharjah (2010)	Stevens Institute of Technology
	University of Tennessee - Chattanooga
	United States Military Academy
	University of Vermont

* Programs with "Management" in the name, ** "Engineering Management" programs, *** "Engineering and Management" programs. The number in parenthesis under ABET accredited programs is the year that the program was first accredited.

Why are all EM related programs listed in the ASEE column in the right hand column of Table 1 not ABET accredited? After all, this field is in fact EM, with the emphasis on the "E" word. Why would ABET accreditation not be a standard benchmark of EM programs and what accounts for the differences in the numbers of the accredited and not accredited programs? The larger goal of our study is to begin the process of exploring the issues behind these questions. As a starting point, this paper investigates the engineering credit content (ECC) of the accredited programs. Our "not so subtle" hypothesis is to find whether the difference in the number of ABET accredited undergraduate programs compared to the ASEE list may be related to the challenges involving capped total program credits and the continuous struggle to meet the math and science and ECC required for ABET accreditation while satisfying the EM program criteria and maintaining relevant content perceived to be important to undergraduates (such as accounting, marketing, and organizational behavior).

Based on the changing nature of technical organizations, what should be the focus of EM undergraduate programs? Programs appear to be tugged in two directions. A number of studies and papers[4, 5, 6, 7] including the ABET criteria[8] call for graduating engineers who can lead teams, manage resources, work in teams, and understand the global context of engineering. This would appear to be the sweet spot of EM programs. However, business, engineering technology, and technology programs can provide these attributes too in their disciplines, too. What do EM programs do differently in this regard?

Parallel to these calls for what some consider more "soft" engineering workplace skills, there is a parallel and equally loud call that traditional engineering competence must not be sacrificed or compromised. Many see these skills as the foundation of an engineering degree and the core bedrock for the 21st century global competitiveness and innovation that the US needs to maintain its standard of living. The National Academy of Engineering summed up these two perspective in the following statement:[7]

> *Technical excellence is the essential attribute of engineering graduates, but those graduates should also possess team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies.*

In addition to these broader engineering perspectives, the ABET EM program criteria provide additional insight into what should be interpreted as special to EM at the undergraduate level (our emphasis underlined):

> *The curriculum must prepare graduates to understand the <u>engineering relationships</u> between the management tasks of planning, organization, leadership, control, and the human element in production, research, and service organizations; to understand and deal with the stochastic nature of management systems. The curriculum must also prepare graduates to integrate management systems into a series of different technological environments.*[8]

Whether in the area of ABET Criterion 3 (a)-(k) student outcomes or in the program criteria, factors such as a restricted and possibly narrow interpretation of engineering topics, university pressures to reduce the total number of credits hours, and the calls from industry to provide a different type of education, require that we rethink and refine the definition of ECC in the curriculum. In summary, we hope to analyze this point and shed light on the apparent disparity between the number of ABET accredited and non-accredited programs by examining how the accredited EM programs address the balance of ECC program content and accreditation requirements. We begin with a more detailed look at the ABET program criteria for EM.

ABET Engineering Management Criteria

Of the many facets of the ABET criteria, for EM programs there are two main issues that must be addressed to attain accreditation. First and foremost is meeting the number of ECC hours required. The ABET program criteria specifies:[8]

> *…one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences*

have their roots in mathematics and basic sciences but carry knowledge further toward creative application focused on the area of design. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

Relative to interpreting this statement for EM related programs, content claimed as ECC should have some basis in providing a bridge between mathematics / science and engineering practice and be a program managed course (per Felder et al.[10], discussed in the next section). An organizational behavior class would not typically accomplish this but on the other hand a course in decision theory, managed or with strong participation by the department/program, including assessment and focused on engineering applications would fit this definition, we believe.

The second consideration for EM is the ABET program criteria which states that[8]:

…the curriculum must prepare graduates to understand the engineering relationships between the management tasks of planning, organization, leadership, control, and the human element in production, research, and service organizations; to understand and deal with the stochastic nature of management systems.

Once again, the program criteria should be best implemented within courses managed by the program and provides engineering context and applications. Unfortunately, this has been a challenge because of declining resources, the growth of business schools, and the traditional "turf" battles inherent in academics.

When these two areas of ABET accreditation criteria are combined with the mandate to reduce or limit credit hours, meeting these requirements and delivering a connected program relevant to industry continues to be a challenge. It is essential to better understand how the current accredited programs handle (i.e., count, define, use, etc.) ECC topics and to understand the apportionment of ECC topics to the program criteria such as "planning, organization, leadership, control and the human element…" topics. This is the focus of the following sections of the paper.

Several additional practical points are important to mention. First, it is essential for EM related programs to avoid the perception that they are "engineering light" and lack the rigor of engineering programs in general, surviving by attracting students who cannot succeed in other engineering disciplines. This perception can potentially taint EM graduates, limit their career prospects, and limit the potential to complete Professional Engineer (PE) registration. In this same vein, ECC credits in areas such as management and leadership, for example, must be differentiated from standard business school courses. Otherwise how does EM position itself as different from "management of technology" or run of the mill "management" programs? The literature review follows, where we examine relevant publications related to these issues and questions.

Literature Review

Our literature review necessarily threw a wide net as we searched for work, not only directly related to the field of EM and similar areas (such as industrial engineering, systems engineering and quality), but also general guidance on definitions of engineering assessment, program structure, and credit definitions. Felder and Brent[11] provide an essential foundation in identifying an engineering related course as justified based on assessment. This paper describes the core process of designing courses to address a-k outcomes as beginning with identification of required courses in the program curriculum, controlled by the program whose content does not vary from one offering to another (our emphasis). These courses in turn should be related to the a-k outcomes with specific, measurable learning objectives. Applying these points to a skill important both to EM and broadly in engineering disciplines, communications (outcome g) for example would not typically be accepted as ECC if it were a three-credit course from the English department. However, a course in engineering communications managed by an engineering program could more appropriately fit these guidelines, especially if tied to presenting mathematics and scientific results.

Starting in the late 1990s and early 2000s, papers began to appear addressing the undergraduate EM curriculum. A paper by Murray and Raper[12] is an example, which focused on the curricular contrast of EM and industrial engineering (IE) programs and used a general course categorization approach. Similarly, Blevins[11] provided an overview of EM program development up to 2002 and notes that at that time there were only three undergraduate ABET accredited EM programs (Stevens Institute of Technology, University of Missouri Rolla, now Missouri University of Science and Technology or MUST, and the United States Military Academy) along with four more with “management” in their titles (Montana State - Bozeman, North Dakota State, Oklahoma State, and Rensselaer Polytechnic Institute). More recently, Elrod et al[13] compared five accredited EM programs with nine industrial engineering (IE) programs at the undergraduate level and the content of undergraduate and graduate EM programs. Once again this work used general categories of topics for the comparative analysis and did not examine engineering related credits. It found significant differences in the EM programs but identified a shared body of knowledge between IE and EM programs as summarized in Table 2.

Table 2. Common Curriculum between IE and EM (Elrod et al.[13])

B.S. in Engineering Management	B.S. in Industrial Engineering
General Management and Leadership	Economics (Micro &/or Macro; Engr Econ)
Accounting	Probability & Statistics
Economics (Micro &/or Macro; Engr Econ)	Operations Research
Probability & Statistics	Ergonomics, Human Factors, Work Design
Operations & Production Management	Production Planning, Inventory Control, Scheduling
Marketing	Systems Analysis
Total Quality Management	Senior Design or Project
Project Management	Automation, Simulation, or Manufacturing Processes
Senior Seminar & Internship or Senior Design	Statistical Process Control & Quality Methods
18 hours in emphasis area	Facilities Design, Material Handling, & Plant Layout

A study by Zander[14] demonstrated this program content diversity found by Elrod et al[13]. Zander[14] examined the common curriculum between seven ABET programs and found that there were only two courses common to all and these are shown in Figure 1, production/ operations management and project management. Overall papers such as these provided a valuable contribution to understanding the range of EM curricula and comparison with other related fields, but did not identify those course areas, which were counted in the ECC category.

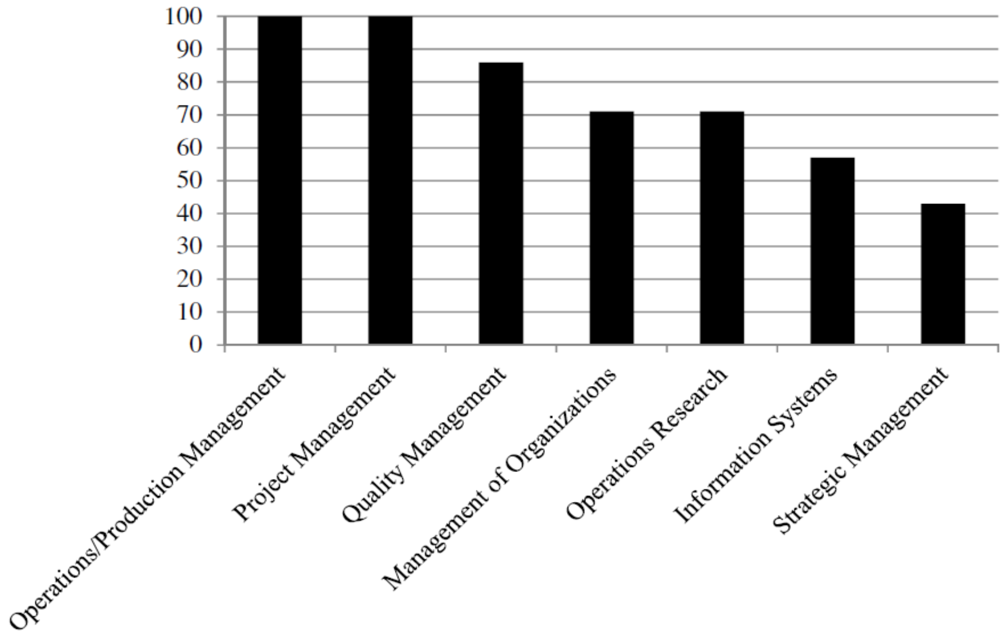

Figure 1. Courses Common to Seven ABET Accredited EM Programs (Zander[14])

From the perspective of engineering societies and their influence on undergraduate curriculum, and accreditation, a number of professional societies have employed the concept of a body of knowledge to guide course decisions and provide a level of uniformity in curricula. Leaders in demonstrating this type of effort are the American Society of Civil Engineers (ASCE) [15] and the American Society of Mechanical Engineers (ASME.)[16] Civil engineering has taken the lead on this effort over the last decade and tied this into a call for graduate education as a requirement for professional registration.[16, 17] These efforts have even led to proposals to define uniform levels of achievement.[18]

Other examples also demonstrate the potential use of a body of knowledge for undergraduate education in a number of engineering fields. [19, 20, 21, 22] The paper by Walesh[22] contains an excellent summary list of professional bodies of knowledge. Matson, Mozrall, Schaub, and Patterson[20] studied program educational objectives, outcomes, and curricula used by IE (or similarly named) programs in their ABET continuous improvement plan and may have direct implication for the topics addressed in this paper. The objective of their study was to identify outcomes common to IE programs that distinguish industrial engineering from other engineering disciplines and might serve as a foundation for a body of knowledge. In turn these perhaps could serve as a foundation to develop an engineering body of knowledge. The study found a strong connection between IE program ABET outcomes (beyond ABET Criteria 3 (a)-(k) student outcomes and curricular content. Specifically it identified these six common topics, metrics for ABET Criteria 3 (a)-(k) student outcomes and proposed consideration that all IE programs contain at least four:

- probability and statistics,

- economic analysis,
- operations research and simulation,
- quality methods,
- project management, and
- ergonomics and work measurement/work design.

We found no specific papers relating the body of knowledge (BoK) for EM and addressing the bridging to ABET undergraduate program accreditation. The EM BoK[23] was first introduced in 2007 in affiliation with ASME and with the third edition became exclusively published by American Society for Engineering Management (ASEM.) Its primary goal is to serve as a foundation for professional certifications and training programs. Unfortunately it was not developed for and has not been used as a guide for curriculum development of ABET accredited undergraduate programs. Several publications address the BoK and the general field of EM and graduate programs but do not shed light on the issues targeted by this paper.[24, 25, 26]

Similarly, we found no guidance or prior work related to the technical or engineering specific content of EM degrees. However the NSPE body of knowledge[21] may provide guidance in this regard. Walesh[22] summarizes the thirty capabilities noted in the National Society for Professional Engineers (NSPE) body of knowledge and their categories: Basic/ foundational, technical, and professional practice) and they cover a range of EM related areas. He also calls for the use of this list to guide accreditation leaders in developing criteria for accreditation.

In summary, our literature review found a significant amount of research exists about what should and could be taught in EM. The student outcomes needed for an EM program to be relevant to industry needs are also well defined. However, little to no literature on how to best implement the desired student outcomes within the ABET requirements was identified. Guidance on how to define ECC specifically tailored to and appropriate for EM programs and how to best implement the topics is needed for EM programs to grow and avoid long term issues associated with ECC credit hour counts. The next section examines how various programs appear to have accomplished this balance.

Results

We next solicited programs for information on how they had addressed balancing their ABET and EM program requirements for ECC topics. Programs with "engineering management" in the name were contacted and asked if they would share, anonymously, the content of Table 5-1 in their last self-study and specific details on whether these courses are "owned" by the program or not. (Table 5-1 in an ABET self-study classifies the program curriculum based on credit categories of math & basic sciences, engineering topics, general education, and other.)

Results for five domestic and one international program are summarized in Table 3. A few explanatory points are important to summarize prior to study of the table:

- The course titles / topical area are noted in the left column with the program credits and ownership listed in the cell on that row. For example for "Capstone" for program D1 claimed five credits of ECC and the course was jointly owned by the Department and the School/College of Engineering.

- Program D5 barely met the minimum ECC requirement yet had the highest number of total credits. That university has a 32-course broad based core. One can see by the fractional number of ECC hours this program is continuously challenged to meet the ABET ECC requirement.
- Program D4 has a large core curriculum across all departments in the school that is engineering focused. Also, they do not rely on other schools/colleges to deliver ET content.
- The two schools that have the fewest number of ET must be aggressive with their ET count for "soft" engineering classes. Note the fractional ET credit hours for program D5.

Table 3 contains several noteworthy themes regarding what may be classified as traditional engineering courses:

- Several were included in four or more of the six programs:
    - engineering economics,
    - statics/ dynamics/ mechanics,
    - circuits,
    - project management,
    - production/ logistics,
    - modeling and simulation,
    - operations research,
    - programming/MIS,
    - total quality management,
    - introduction to engineering management.
- Several were included in three of the programs:
    - thermodynamics/thermal,
    - statistics and statistics for engineers,
    - materials,
    - process engineering.

Table 3. Engineering Credit Content (ECC)

	Domestic[1]					International
Course/Topical Area	Program D1	Program D2	Program D3	Program D4	Program D5	Program I1
Accounting		1 (D&O)	1.5 (D)	0 (D)		3 (D)
Capstone	5 (D&E)	3 (E)	3 (D)	8 (D)	7 (D)	4 (D)
Circuits/Intro to EE	3 (E)	3 (E)	3 (E)	3 (E)		3 (D)
Engineering Economics		1 (O)	2 (D)	4 (D)	2.5 (D)	3 (E)
Engineering Electives	18 (D&E)	9 (D&E)	15 (D&E)		9 (D&E)	6 (D)
Entrepreneurship		2 (D)		0 (E)		
Facilities						3 (D)
Finance		0 (O)	1.5 (D)			
Fluids		3(O)				
General Engineering Design				11 (E)		
Graphics				1 (E)		1 (D)
Innovation		3 (D)				3 (D)
Intro to EM	6 (D)		3 (D)	3 (D)		2 (D)
Introduction to Engineering	3 (E)		1 (E)			
Law for Engineers/Law	3 (E)	0 (O)			0 (O)	
Manufacturing/Automation						6 (D)
Marketing	0 (D)	0 (O)	3 (D)			
Materials	3 (E)	3 (E)		3 (E)		
Modeling and Simulation	3 (D)			3 (D)	3 (D)	3 (D)
Operations Research	3 (D)	3 (D)		3 (D)	6 (D)	5 (D)
Organizational Behavior	2 (D&O)	3 (D&O)			3 (O)	
Probability and Statistics - General	0 (D)				.5 (O)	0 (D)
Process Engineering				3 (D)		3.5 (D)
Production/Logistics	3 (D)	3 (D)	3 (D)	3 (D)	3 (D)	6 (D)
Programming/MIS/ Information Systems	0 (E)	2 (D&O)	3 (E)	3 (D)	.5 (E)	7 (D&E)
Project Management		3 (D&O)	3 (D)	3 (D)	3.5 (D)	3 (D)
Safety						3 (D)
Seminar	1 (E)				1 (D)	1 (D)
Statics/Dynamics/Mechanics	3 (E)	3 (E)	9 (E)	4 (E)		
Statistics for Engineers				0 (D)	2 (D)	0 (D)
Systems Engineering				3 (D)	6 (D)	
Thermodynamics/Thermal		3 (E)	3 (E)	3 (E)		
Total Quality Management	0 (O)		3 (D)	3 (D)		3 (D)
Engineering Topics[3]	54	53	60+	66	48	68+
Total Degree	128	122+	128	139	144+	142+

[1]Programs all have ‘Engineering Management’ in their title
[2]D/E/O Department, School of Engineering, or Other Owned
[3]These columns will not add up to the totals because in many cases (such as electives) a or ET credits range was given. We chose the general engineering option as the baseline for the program with different tracks.

Note that some undercounting of courses exists for the general engineering knowledge classes. For example, in program D5 traditional classes such as statics, thermodynamics, and circuits are often electives for the program.

Of the courses many consider to be important for EM but might be debated as potential ECC several were commonly included:

- accounting (4 programs),
- innovation (2 programs),
- marketing (3 programs),
- organizational behavior (3 programs).

A closer examination of these "engineering management" oriented courses and how they are implemented and counted shows several common themes:

- Those which are counted as engineering credit are often partial credit. For example, accounting in program D3 is only 1.5 credits of engineering.
- In general, if a course is counted as engineering credit, it is owned by the department or the school / college of engineering and is not owned by a support department such as business. We infer from this that the course is taught by a program faculty member with an engineering background who has EM or technical operations experience.
- Finally, the programs have sufficient engineering credits in total so that the ABET requirement for 1.5 years equivalent credits of engineering content would not be jeopardized if a small number of these credits were not counted in the ECC category. For example, program D1 has an organizational behavior class, apparently jointly taught, which claims two credits of engineering content. Since the program has 54 credits of engineering in a 128-credit program, it would still meet the 48-credit requirement if one or two of these credits were not counted. Excess ET capacity is critical for EM programs.

Summary and Conclusions

This paper is the first step in developing a more transparent understanding of how EM content can bridge to and support ABET ECC content. In general, we hope this body of work can be a foundation to guide the structure of what might sometimes be considered soft classes so that they can be validated as containing ECC content and credit. The comparisons provided in this paper are a beginning in building this understanding of ECC content in the EM discipline. We offer the following conclusions and supporting recommendation based upon this research:

Conclusion 1. Classes focused on such topics as controlling, staffing, and planning that are required to meet program specific criteria, especially in programs with large non-engineering requirements, typically must be owned and tailored to engineering applications by the EM program in order to meet the ECC credit requirements. Business schools that often own these classes must be made to understand that they must be taught in this context for accreditation or allow the EM programs to teach the classes.

Conclusion 2: Courses such as controlling, staffing, planning, etc., if claimed as ECC for EM programs must be designed and taught with engineering relationships. A generic version, not specifically focused on engineering management, is not appropriate for an EM program since it is no different from a business course or a management of technology course.

Recommendation: These relationships must be highlighted, assessed and evaluated in the self-study. Some type of committee structure should be in place to monitor/assess the ECC content for these types of classes. A particularly important attribute of courses like this could be use of the mathematical skills of the EM students. For example, optimization could be used for staffing applications and stochastic processes in controlling and planning to clearly differentiate these as having ECC content appropriate for EM.

Conclusion 3: Based on the points noted above, it is time to formalize across the EM discipline the concept that courses considered soft engineering can count as ECC if formulated, managed, assessed, and delivered with a clear EM flavor. This step will provide a foundation for a consistent perspective from a variety of program evaluators. The EM discipline is a big tent and we must be able to accommodate a range of perspectives but also identify what is the common ground we share. The perspectives from this paper can provide a consistent context, both for those in the EM discipline with a more traditional, quantitative view of engineering management and those who see the discipline as closer to traditional management, to minimize varying views on the ECC count. Program evaluators who come from a very traditional engineering background will be hard to sway that, for example, an organizational behavior course contains ECC.

Based on our last conclusion, we recommend that professional societies, such as the American Society for Engineering Management (ASEM) or the Institute of Industrial Engineers (IIE), should conduct a more specific curriculum review at the undergraduate level of EM programs to provide additional guidance on undergraduate EM curricular matters. This paper provides a starting point for this effort.

Building on this discussion and the improved understanding that should result in the longer term, we hope to see the growth of additional EM programs and an increase in the EM programs listed in the ASEE data base that become ABET accredited.

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