AC 2011-97: LESSONS LEARNED IN IMPLEMENTING AND ACCREDITING A MANUFACTURING ENGINEERING PROGRAM

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Lessons learned in implementing and accrediting a Manufacturing Engineering program.

Abstract

Spurred on by an explosive growth in high technology and semiconductor manufacturing industries in the State of Texas and central Texas in particular in the 1990s, Texas State University established its first engineering program in Manufacturing Engineering in 2000. Since, significant changes have occurred in the world of manufacturing both globally and locally. The advent of intense global competition has placed unprecedented demands on the US manufacturing sector. The most conspicuous result of these developments is the movement of manufacturing industries from across the nation and central Texas to other parts of the world. During this period, our program grew and prepared itself for the ABET accreditation process. This process entailed revisiting our program's goals and objectives in the context of the input we received from our industrial advisory committee, students and graduates, faculty, and ABET as well as changes that occurred in the manufacturing sector in the last decade. This paper presents an analysis of changes that were necessitated owing to aforementioned input in order to achieve accreditation by ABET.

Introduction

At Texas State University, a new degree in manufacturing engineering was offered beginning in Fall 2000[1] . This degree was the outcome of developments in the economy of the State of Texas in the preceeding two decades. By the mid 1990s, the cities of Austin, San Marcos, and San Antonio had all become part of one high-technology industrial corridor that stretched along Interstate Highway 35. Several manufacturing companies such as Applied Materials, Samsung Semiconductors, Freescale, AMD, National Instruments, Dell Computers, Tokyo Electron Limited, etc. had opened new facilities along this central Texas corridor[2]. In an article entitled "1998 Next Century Economy : Sustaining the Austin Region's Economic Advantage in the 21st Century", a report prepared for the Greater Austin Chamber of Commerce, the authors stated that central Texas in the 1990s had added more technology jobs than Silicon Valley, Boston's Route 128, or the Research Triangle in North Carolina[3]. However, simultaneous with these outstanding economic gains, there was a lack of availability of a skilled professional workforce in central Texas. Several studies had attested to a chronic and crippling shortage of manufacturing professionals in this geographic area[4,5]. Many industries were considering relocating elsewhere in the U.S. or outside the country if qualified manufacturing professionals with the ability to design, monitor, and control processes could not be found. Therefore, being a public university, Texas State University made a strategic decision to offer a degree in Manufacturing Engineering with the intention of addressing regional industrial imperatives. The following section provides an overview of the degree and the curriculum.

The Manufacturing Engineering Degree

The design of the degree was strongly motivated by the criteria laid down by ABET, studies conducted by the Society of Manufacturing Engineers (SME), and the industrial distribution in

Texas. Since the economic downturn of the 1980s, the economy of Texas had become very diverse. Thus, in addition to petrochemicals, other industries such as semiconductor manufacturing, telecommunications, computer manufacturing, metal casting, metal fabrication, plastics and composites manufacturing etc. were represented in the industrial mix. Therefore, it was determined that the degree to be offered at Texas State University would offer two concentrations: one in general manufacturing and the other in semiconductor and high-technology manufacturing. The intent was that the former concentration would produce a generalist who would prove beneficial to a multitude of manufacturers located all through the state and that the latter would address the workforce needs of the high-technology saturated corridors of central Texas and the Dallas-Fort Worth metroplex.

The specifics of the curriculum design were firstly guided by the ABET criteria for accrediting Manufacturing Engineering programs. The program-specific portions of the criteria guidance that were consulted are indicated in Table 1[6].

Table 1 – ABET Criteria for Manufacturing Engineering Curriculum
Materials and manufacturing processes: understanding the behavior and properties of materials as they are altered and influenced by processing in manufacturing.
Process, assembly and product engineering: understanding the design of products and the equipment, tooling and environment necessary for their manufacture.
Manufacturing competitiveness: understanding the creation of competitive advantage through manufacturing planning, strategy and control.
Manufacturing systems design: understanding the analysis, synthesis and control of manufacturing operations using statistical and calculus based methods.
Laboratory experience: graduates must be able to measure manufacturing process variables in a manufacturing laboratory and make technical inferences about the process.

Similarly, guidance came from the findings of a study conducted by SME, the goal of which was to identify competency gaps on the part of newly graduating manufacturing engineers[7] . The study identified gaps of varying severity in the following areas:

Communication Skills
Teamwork
Manufacturing Principles
Reliability
Project Management
Manufacturing Processes
Business Skills
Change Management
Quality
Statistics and Probability
Ergonomics

Materials
Lifelong Learning

Additional guidance came from an examination of the best practices and curriculum content of exemplar manufacturing engineering programs in the U.S. These included Brigham Young University, General Motors Institute (now Kettering University) and Worchester Polytechnic Institute. Based on the input from the abovementioned sources and the specific stakeholders of the Texas State University Manufacturing Engineering program, the mission statement, educational objectives, and educational outcomes were developed.

Mission Statement

After several revisions made in consultation with the program's stakeholders, the Texas State University Manufacturing Engineering Mission Statement was created. The Mission Statement for the program is:

Our mission is

- To sustain a quality, student-centered, industry-oriented engineering curriculum.
- To attract students and prepare them with the knowledge, practical skills, and abilities to perform
  as highly competent engineers in the global marketplace and/or in graduate studies.
- To produce graduates skilled in materials and manufacturing processes; process, assembly and
  product engineering; manufacturing competitiveness and systems design.

There are several tenets expressed in the mission statement which indicate the desired direction for the program. Texas State University has a century-long tradition as the pre-eminent educators' university in Texas. This tradition of student-centered education reflected in the university-wide mission statement is reiterated here. The industrial orientation offers a difference from many programs at Texas State University, most of which are traditional "liberal arts" programs. The uniquely rich industrial environment in the central Texas corridor offers the opportunity for the program to offer strong local synergy. While the Manufacturing Engineering program currently offers only the baccalaureate program, it is important to prepare students matriculating the program either to enter careers directly or to pursue further scholarly depth. Future plans to expand into offering graduate degrees at Texas State University are proceeding.

Program Educational Objectives

After several revisions made in consultation with the program's stakeholders, the Texas State University Manufacturing Engineering Program Educational Objectives (PEO) were created. The PEO are:

The objectives of the program are to produce graduates who:

1. Perform as engineering leaders in the global marketplace.

2. Understand and apply the principles of math, science, and engineering in design and manufacturing related activities.
3. Contribute to the profitable growth of manufacturing businesses.
4. Maintain high standards of professional and ethical responsibility.
5. Practice lifelong learning.

Among these PEOs, the influence of the industrial stakeholder input is especially evident in PEO #3. Making the students directly aware of the profit equation in their projects is an important preparation for industrial careers.

Program Outcomes

After several revisions made in consultation with the program's stakeholders, the Texas State University Manufacturing Engineering Program Outcomes (PO) were created. The PO as they existed prior to the initial ABET accreditation evaluation are:

Each graduate is expected to have:

1. An ability to apply the principles of math, science, and engineering to the solution of practical problems.
2. An ability to plan and conduct experiments and interpret the results of the experiment.
3. An ability to design a system, component, or process to meet desired needs.
4. An ability to function effectively on a multi-disciplinary team.
5. An understanding of professional and ethical responsibility.
6. An ability to communicate effectively.
7. An awareness of the impact of engineering solutions in a global and societal context
8. An awareness and commitment for life-long learning.
9. An awareness of contemporary issues.
10. An ability to use modern engineering tools and techniques in engineering practice.
11. An understanding of the financial and business aspects of engineering decision making.

The Program Outcomes are related to ABET EC 2000 Criterion 3. The differences between the POs and the Criterion 3 components are relatively minor and were intended to align the PO list more closely to the PEO list. The most direct example is PO #11 which references the financial and business aspects of engineering. During the ABET visit, the composition of the PO list was the source of comment by the ABET visitors. The strong recommendation of the accreditation review team was for the program to revise the PO list to match the Criterion 3, a-k outcomes exactly and, if desired, add our own PO only after the 11 from Criterion 3.. The program initiated a review of the PO list with the constituents in the light of these recommendations and the current PO list now matches ABET Criterion 3, a-k exactly.

Manufacturing Engineering Curriculum

As mentioned earlier, the Texas State University Manufacturing Engineering curriculum offers two concentrations, general manufacturing and semiconductor manufacturing. These two curricula are summarized in Figures 2 and 3. The courses in the respective curricula are listed by credit hour content in three categories as determined by the Manufacturing Engineering faculty: General Education (core curriculum); Mathematics and Basic Sciences; and Engineering Topics. The General Education portion of the curriculum is required by Texas State University to be at least 46 hours. This includes hours which have been reassigned in Figures 2 and 3 into the Mathematics and Basic Sciences category. The ABET accreditation guidelines set minimum levels of 32 hours for Mathematics and Basic Sciences and 48 hours for Engineering Topics.

The General Education component is considerable larger than the exemplar programs at other institutions reviewed when forming the program. However, this core curriculum is not negotiable. Both versions of the curriculum easily surpass the Engineering Topics minimum. Both, however, are at the minimum for Mathematics and Basic Sciences. The ABET visitation team strongly recommended increasing the Mathematics and Basic Science content as the interpretation of amount of content in certain courses, especially MATH 3375: Engineering Mechanics could be interpreted as better fitting with Engineering Topics. As a result, the two Manufacturing Engineering curricula have since been modified to include the addition of MATH 3377: Linear Algebra and one additional Mathematics or Basic Science Elective in both programs.

Texas State Manufacturing Engineering - General					
		Math and Basic Sciences	Engineering Topics	Design	General Education
Semester	**Courses**				
Fr. Fall/Soph. Fall	any two PFW classes				2
Freshman Fall	CHEM 1341/1141: General Chemistry I/Lab	4			(*required for Core curriculum*)
Freshman Fall	ENG 1310: College Writing, Part I				3
Freshman Fall	ENGR 1413: Engineering Design Graphics		4		
Freshman Fall	MATH 2471: Calculus I	4			(*required for Core curriculum*)
Freshman Fall	US 1100: University Seminar				1
Freshman Spring	ENG 1320: College Writing, Part II				3
Freshman Spring	ENGR 2300: Materials Engineering	1	2		
Freshman Spring	MATH 2472: Calculus II	4			
Freshman Spring	one of ART,DAN,MU, or TH 2313				3
Freshman Spring	PHYS 1430: Mechanics	4			(*required for Core curriculum*)
Sophomore Fall	HIST 1310: History of the United States to 1877				3
Sophomore Fall	IE 3320: Engineering Statistics	3			
Sophomore Fall	MATH 3323: Differential Equations	3			
Sophomore Fall	MFGE 2332/TECH 2332 Material Selection and Manufacturing Processes		3		
Sophomore Fall	PHYS 2425: Electricity and Magnetism	4			
Sophomore Spring	COMM 1310: Fundamentals of Human Communication				3
Sophomore Spring	CS 1428: Foundations of Computer Science		4		
Sophomore Spring	ECO 2301: Principles of Microeconomics				3
Sophomore Spring	HIST 1320: History of the United States, 1877 to date				3
Sophomore Spring	MATH 3375: Engineering Mechanics	3			
Junior Fall	ENGR 3311 Mechanics of Materials		3		
Junior Fall	ENGR 3373 Circuits and Devices		3	X	
Junior Fall	MFGE 4396 Manufacturing Systems Design (WI)		3	X	
Junior Fall	MGT 3303 Introduction to Management		3		
Junior Fall	PHIL 1305: Philosophy and Critical Thinking				3
Junior Spring	ENGR 3315: Engineering Economic Analysis	2	1		
Junior Spring	IE 3330/TECH 3364 Quality Assurance		3		
Junior Spring	MFGE 3316/ENGR 3316 Computer Aided Design		3		
Junior Spring	MFGE 4376 Control Systems and Instrumentation		3		
Junior Spring	one Literature of ENG 2310, 2320, 2330, 2340, 2359, or 2360				3
Junior Spring	POSI 2310: Principles of American Government				3
Senior Fall	IE 3360/TECH 4345 Methods Engineering and Ergonomics		3	X	
Senior Fall	Manufacturing Processes Elective (TECH 1330, TECH 4330, MFGE 4367, MFGE 4392)		3		
Senior Fall	MFGE 4363 Concurrent Process Engineering (WI)		3	X	
Senior Fall	MFGE 4395 Computer Integrated Manufacturing (WI)		3	X	
Senior Fall	POSI 2320: Functions of American Government				3
Senior Spring	Manufacturing Processes Elective (TECH 1330, TECH 4330, MFGE 4367, MFGE 4392)		3		
Senior Spring	Manufacturing Systems Management Elective (IE 4355, IE 4380, MATH 3348)		3		
Senior Spring	MFGE 4365 Tool Design		3	X	
Senior Spring	MGT 4330 Production and Operations Management		3		
		Math and Basic Sciences	Engineering Topics		General Education
	Totals - ABET Basic-Level Requirements	32	59		36
	Overall total for Degree	127			
	Percent of Total	25.2%	46.5%		28.3%
Totals must	Minimum Semester Hours Required	32	48		
satisfy one set	Minimum Percentage	25.0%	37.5%		

Figure 2: General Manufacturing Curriculum

Texas State Manufacturing Engineering - Semiconductor					
		Math and Basic Sciences	Engineering Topics	Design	General Education
Semester	**Courses**				
Fr. Fall/Soph. Fall	any two PFW classes				2
Freshman Fall	CHEM 1341/1141: General Chemistry I/Lab	4			(*required for Core curriculum*)
Freshman Fall	ENG 1310: College Writing, Part I				3
Freshman Fall	ENGR 1413: Engineering Design Graphics		4		
Freshman Fall	MATH 2471: Calculus I	4			(*required for Core curriculum*)
Freshman Fall	US 1100: University Seminar				1
Freshman Spring	ENG 1320: College Writing, Part II				3
Freshman Spring	ENGR 2300: Materials Engineering	1	2		
Freshman Spring	MATH 2472: Calculus II	4			
Freshman Spring	one of ART,DAN,MU, or TH 2313				3
Freshman Spring	PHYS 1430: Mechanics	4			(*required for Core curriculum*)
Sophomore Fall	HIST 1310: History of the United States to 1877				3
Sophomore Fall	IE 3320: Engineering Statistics	3			
Sophomore Fall	MATH 3323: Differential Equations	3			
Sophomore Fall	MFGE 2332/TECH 2332 Material Selection and Manufacturing Processes		3		
Sophomore Fall	PHYS 2425: Electricity and Magnetism	4			
Sophomore Spring	COMM 1310: Fundamentals of Human Communication				3
Sophomore Spring	CS 1428: Foundations of Computer Science		4		
Sophomore Spring	ECO 2301: Principles of Microeconomics				3
Sophomore Spring	HIST 1320: History of the United States, 1877 to date				3
Sophomore Spring	MATH 3375: Engineering Mechanics	3			
Junior Fall	ENGR 3311 Mechanics of Materials		3		
Junior Fall	ENGR 3373 Circuits and Devices		3	X	
Junior Fall	MFGE 4396 Manufacturing Systems Design (WI)		3	X	
Junior Fall	MGT 3303 Introduction to Management		3		
Junior Fall	PHIL 1305: Philosophy and Critical Thinking				3
Junior Fall	TECH 4374 Digital Electronics		3		
Junior Spring	ENGR 3315: Engineering Economic Analysis	2	1		
Junior Spring	IE 3330/TECH 3364 Quality Assurance		3		
Junior Spring	MFGE 3316/ENGR 3316 Computer Aided Design		3		
Junior Spring	MFGE 4376 Control Systems and Instrumentation		3		
Junior Spring	one Literature of ENG 2310, 2320, 2330, 2340, 2359, or 2360				3
Junior Spring	POSI 2310: Principles of American Government				3
Junior Summer	TECH 4375 Computer Circuit Electronics		3		
Senior Fall	IE 3360/TECH 4345 Methods Engineering and Ergonomics		3		
Senior Fall	Semiconductor Manufacturing Elective (PHYS 4320, PHYS 4340, MFGE 4394)		3		
Senior Fall	MFGE 4363 Concurrent Process Engineering (WI)		3	X	
Senior Fall	MFGE 4395 Computer Integrated Manufacturing (WI)		3	X	
Senior Fall	POSI 2320: Functions of American Government				3
Senior Spring	MFGE 4392/TECH 4392 Microelectronics Manufacturing		3		
Senior Spring	Manufacturing Systems Management Elective (IE 4355, IE 4380, MATH 3348)		3		
Senior Spring	MFGE 4365 Tool Design		3	X	
Senior Spring	MGT 4330 Production and Operations Management		3		
		Math and Basic Sciences	Engineering Topics		General Education
	Totals - ABET Basic-Level Requirements	32	65		36
	Overall total for Degree	133			
	Percent of Total	24.1%	48.9%		27.1%
Totals must	Minimum Semester Hours Required	32	48		
satisfy one set	Minimum Percentage	25.0%	37.5%		

Figure 3: Semiconductor Manufacturing Curriculum

Results of the ABET Review Process

The ABET review team identified several areas of concern in their preliminary report. The most significant area of concern was also the most addressable prior to the accreditation decision. The composition of the curriculum relative to the minimum content required by the ABET guidelines in the areas of Mathematics and Basic Sciences and Engineering Topics was called into question. The review team identified several courses listed in the curricula of Figures 2 and 3 that were misidentified in category. The reviewers reassessed MGT 3303: Introduction to Management, MGT 4330: Production and Operations Management, CS 1428: Foundations of Computer Science, and ENGR 1413: Engineering Design Graphics from Engineering Topics to General Education. Similarly, the “Manufacturing Process Elective” was disallowed due to the inclusion of TECH 1330 as an option citing the potential for a lower-division course to lack the necessary rigor for an elective course. The reviewers suggested that MATH 3375: Engineering Mechanics was better placed in Engineering Topics than Mathematics and Basic Sciences. These reassignments placed the curriculum at risk of failing to meet the minimum criteria. The immediate response to this course reassessment involved several changes to the curriculum. MATH 3377: Linear Algebra was added as a required course in the curriculum. Similarly, a Math and Science Elective (3 hours) which consists of either MATH 3373: Calculus III, CHEM 1342: Chemistry II, or PHYS 2435: Waves and Heat was added to the curriculum. ENGR 1413 was enhanced by strengthening both finite element analysis and rapid prototyping content. The intent of these changes is to allow ENGR 1413 to be assigned to the Engineering Topics category for future accreditation cycles. TECH 1330 was removed as an option for the Manufacturing Process Elective so that the Manufacturing Process Elective would be allowed to remain in the Engineering Topics category. The Manufacturing Systems Management Elective was redirected to become a required course, IE 4355: Facilities Planning. Once these actions were taken and presented to the ABET review team in the form of the 30-day due-process response, the level of concern was reduced and the criteria was met.

The more minor areas of concern are items which were not quickly addressable. The recommendation of the reviewers was to revisit the PEO and PO lists with the various stakeholders as well as to enhance our assessment of the outcomes. One specific reviewers' recommendation was to discuss the PO list with the stakeholders and realign them to match ABET Criterion 3. Since this recommendation the faculty have sought input and consensus from all of the program stakeholders. The result of the stakeholder input is to rewrite the PO list to match the ABET Criterion 3 list as recommended.

After consultation with stakeholders the following decisions were made. The mission and PEOs would not undergo any changes. The POs were changed to be aligned exactly with the ABET 3, a-k outcomes. The new POs are as follows:

Each graduate is expected to have:

An ability to apply knowledge of mathematics, science, and engineering.
An ability to design and conduct experiments, as well as to analyze and interpret data.

An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
An ability to function on multidisciplinary teams.
An ability to identify, formulate, and solve engineering problems.
An understanding of professional and ethical responsibility.
An ability to communicate effectively.
The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
A recognition of the need for, and an ability to engage in life-long learning.
A knowledge of contemporary issues.
An ability to use the techniques, skills, and modern engineering tools necessary for engineering.

Conclusions

The ABET review process followed the established curriculum with a self-study that targeted the 2008-2009 academic year followed by an ABET team visit in Fall 2009. The reviewers identified several areas of potential concern which were immediately addressable in the 30-day due-process response. The program made several changes in light of the recommendations of the ABET review team. Consequently, the review of the two curriculum concentrations ultimately led to accreditation during the Summer 2010 annual ABET meeting.

In terms of lessons from the process, we found that our mission and PEOs being fairly broad in outlook did not undergo changes either on account of changes in the economy or the accreditation processes. The POs were changed. The key change was a one to one map of the initial POs with the ABET 3, a-k outcomes. Our experiences suggest that it would be prudent to adhere as closely as possible to ABET's terminology and definitions. The keeps both the institution and the ABET visiting team on the same page. In regard to specific curricular content, we recommend that engineering programs evaluate carefully all mathematics, basic science, and engineering topics content that students rely upon from courses taken from outside the department. Examples might include Engineering Mechanics from the Mathematics department or Production and Operations Management from the Management program of the Business School.

All in all, our experience with the accreditation process was positive. At the successful conclusion of this long and arduous process we feel we have, in the truest traditions of continuous improvement, moved the program forward.

Bibliography

[1] Sriraman, V. and Habingreither, R. (2002) A New Degree Program in Manufacturing Engineering, Proceedings of the 2002 CIRP International Manufacturing Education Conference, Twente, The Netherlands.

[2] Habingreither, R., Sriraman, V. and Batey, A. (2000) Manufacturing Engineering Degree Proposal, Proposal submitted to the Texas Higher Education Coordinating Board, Austin, TX.

[3] Greater Austin Chamber of Commerce (1998) 1998 Next Century Economy : Sustaining the Austin Region's Economic Advantage in the 21st Century, Greater Austin Chamber of Commerce, Austin, TX.

[4] Engibour, T. (1998) The Coming Crisis in the Semiconductor Workforce, Semiconductor Industry Association, Washington, DC.

[5] Swindle, J.E. (1997) Manufacturing, Texas Lyceum Journal, Volume 13, Number 2.

[6] ABET (1997) ABET Engineering Criteria 2000, Accreditation Board for Engineering and Technology, Inc., Baltimore, MD.

[7] SME (1997) Manufacturing Education Plan, Society of Manufacturing Engineers, Dearborn, MI.