EVOLUTION OF AN INDUSTRIAL ENGINEERING CURRICULUM

John E. Shea, Thomas M. West
Oregon State University

Introduction

At the beginning of this decade, the structure of engineering curricula at most colleges and universities had existed since the early 1950's, and reflected an emphasis on a solid foundation in math, science, and engineering science as expressed in the Grinter Report of 1955[1]. The requirements for accreditation by the Accreditation Board for Engineering and Technology (ABET) reinforced this traditional structure of the engineering curricula.

The advent of ABET's new engineering criteria, Engineering Criteria 2000 (ABET 2000), will significantly influence future directions in the development of engineering programs. As the new accreditation criteria begin to take effect, it is important to step back and reflect on the tremendous evolution that has taken place during the decade. This paper presents an overview of the curriculum and pedagogy changes that have occurred in the Industrial and Manufacturing Engineering (IME) department at Oregon State University (OSU). A review of the events and factors that shaped the changes makes it apparent that many people and events shaped a significant evolution in the undergraduate academic program.

Changes to the IME Curriculum

OSU's College of Engineering (COE) awards approximately 500 undergraduate degrees annually in twelve programs housed in eight departments. The 12-quarter, 192 credit hour, curriculum is evenly divided into pre-engineering and professional engineering. Most of the pre-engineering curriculum is common to all of the departments. Because most of the pre-engineering courses are coordinated through the COE, improvements to the IME curriculum have focused primarily on upper division courses taught within the department.

Seventy-nine of the 192-quarter credit hours consist of IME courses. This portion of the curriculum has evolved with changes in the industrial engineering profession while maintaining a focus on traditional professional topics such as production scheduling, quality assurance, workplace and facility design, mathematical optimization, and manufacturing processes. Since the formation of the department in 1972, these courses have been taught using conventional instruction methods as summarized in the left-hand column in Table 1.

One consequence of this traditional evolution has been an engineering culture where engineers are characterized as being vertical (in-depth) thinkers who work individually, and who reduce problems to small, manageable and predictable pieces in order to apply their knowledge of science and technology[2]. The result has been the evolution of a self-selection process where the majority of students that select and stay in engineering are those who fit the culture.

Table 1. Changes in the Characteristics of the IME curriculum during the 90's

Characteristics at the Start of the 90's	Characteristics at the End of the 90's
1. Exclusively lecture format	Active learning exercises, collaborative learning
2. Structured laboratory exercises	Guided design laboratories
3. Design primarily confined to senior design project	Design projects integrated at all levels
4. Isolated courses focused on specific topics	Topical material integrated into advanced courses
5. Single discipline upper-level courses	Multi-discipline upper-level courses
6. Emphasis on individual student work	Group projects combined with individual work
7. Few written and verbal communication assignments	Written assignments, reports, presentations
8. Courses focused on theory to solve textbook problems	Theory combined with plant tours, real-world problems
9. Limited contact with practicing professionals	Guest lectures, MECOP mentors, project presentations include "customers"
10. Low utilization of educational technologies	Progressive integration of computers into professional coursework
11. Limited feedback from students, employers, constituents	Multiple advisory boards, mid-term and end-term course feedback and evaluation
12. Curriculum design based on faculty preferences	Curriculum incorporates multiple sources of feedback
13. Assessment limited to right-answer questions	Assessment of more complex skills and learning objectives

However, there were reasons why traditional engineering curricula needed to change. The majority of graduates from undergraduate programs are employed in the industrial sector where there is seldom a close match between elements of their engineering education and the skill set required for success in the business environment. Job requirements have changed considerably due to rapidly changing technology, increased international competition, and the growing use of quality management principles and tools. Society has also become more racially and culturally diverse, and women and minorities are increasingly expected to be well represented in the engineering profession.

Many in academia understood the existence and characteristics of the forces and direction for change in engineering education. Bordogna et al.[2] believe that engineers should also be characterized as lateral thinkers who work in teams, and are good at designing solutions to satisfy many, often competing, objectives. Industry representatives and members of academia have similar lists of desirable skills that engineering graduates should possess. A composite list illustrative of this skill set is shown in Table 2[3 – 7].

Table 2. Composite list of Desirable Skills of Engineering Graduates

- Written and verbal communication.
- Understand business strategy.
- Appreciation for world cultures, language, political and social systems.
- Able to integrate across technical and non-technical disciplines.
- Lifelong learning.
- Understanding of quality management.
- Intuitive sense, able to go beyond models.
- Experience solving open ended, real-world problems with trade-offs, constraints, and ambiguity.
- Working in teams and individually.
- All aspects of engineering design (tools, process, creativity, technology, customer requirements, system implications).
- Sense of what engineers do and why.

The extent of the changes that engineering colleges must make in response to these changing requirements is similar to the transformation that many domestic corporations have undergone over the past decade. These changes will impact entire engineering departments with the requirement of new courses, the teaching of more complex skills to a more diverse student population, changes to teaching pedagogy, expanded faculty responsibilities, and more emphasis on qualitative assessment of student performance. Most engineering faculty are not fully prepared for these changes.

On the positive side, improvements are currently being made. One strategy for responding to these changing requirements is to develop alternatives for restructuring the engineering curriculum. The National Science Foundation (NSF) established six engineering coalitions each of which was composed of six to eight engineering schools. Funding for each coalition was approximately $15M over five years. Although each coalition had specific objectives, they shared the following common themes[8, 9].

- Increase the retention rate of US students.
- Increase the number of engineering graduates, especially among women and minorities.
- Eliminate repeating high school math and science courses in the core engineering curriculum.
- Integrate design and open-ended problems into the first two years.
- Develop innovative ways to teach engineering.
- Cooperative work in teams.
- Provide a perspective on engineering in society.
- Develop learning modules using video and/or software for use by other institutions.

In response to input from NSF, the Engineering Dean’s Council and other sources, ABET encouraged the Engineering Accreditation Council (EAC) to develop new approaches to undergraduate engineering accreditation by providing a path for engineering schools to maintain accreditation while making the appropriate curricula changes. With the new Engineering Criteria 2000, ABET/EAC will focus on processes and outcomes while placing less emphasis on credit hour content in specific categories.

Although our department did not participate in one of the NSF Coalitions, we actively participated in curricula workshops sponsored by both ABET and NSF. Many of the principles developed in the workshops were incorporated into the IME curriculum. The breadth and depth of the changes became readily apparent last summer when the department displayed the curriculum for a local science festival. It included posters, project assignments and hands-on examples from freshman, sophomore, junior and senior level IME courses. Many practicing engineers who went through the more traditional curriculum were extremely impressed by the new education model.

Several of the changes incorporated in the new IME curriculum are summarized in the right hand column in Table 1. It is important to recognize that the changes are multi-faceted. Many of the concepts have been incorporated in all of the department's courses and each of the years in the program. It is insightful to step back and reflect on the changes during the decade and recognize that many of the ideas on curriculum improvements have been and are continuing to be implemented.

As engineering departments contemplate how to meet the new accreditation requirements, it is important to understand the factors that contributed to the successful evolution of the curriculum. Although the specific factors leading to the changes necessary for ABET 2000 accreditation may be different, understanding the complexity of the process will provide insight into how to make the necessary improvements.

Events and Factors That Have Shaped the IME Curriculum

Extensive changes like those described above evolved over several years and are the result of many contributing factors. Figure 1 shows the timeline of the events and resulting curriculum changes that have occurred during the last two decades. For the IME department, the establishment of a highly structured work cooperative program in the early 1980's provided a new learning opportunity for our students and set the foundation for expanded communication between the department and local industry. Several events exposed faculty to the concepts embedded in the total quality movement[10]. The IME faculty were very receptive to the ideas and, with the support and participation by the administration, developed many ways to improve their courses and the curriculum.

Multiple Engineering Cooperative Program (MECOP)

The department established an option in Manufacturing Engineering in 1981 and received ABET/EAC accreditation for the program in 1984. An innovative component of this program was the establishment of a cooperative program which required two six-month paid internships at two of the participating companies.

MECOP company representatives interview students for selection into the program and placement for each of their assignments. Students are assigned an industrial mentor who guides their experiences and provides periodic feedback. Following each internship, students return to campus and describe their experiences and professional development in a written report and a seminar presentation.

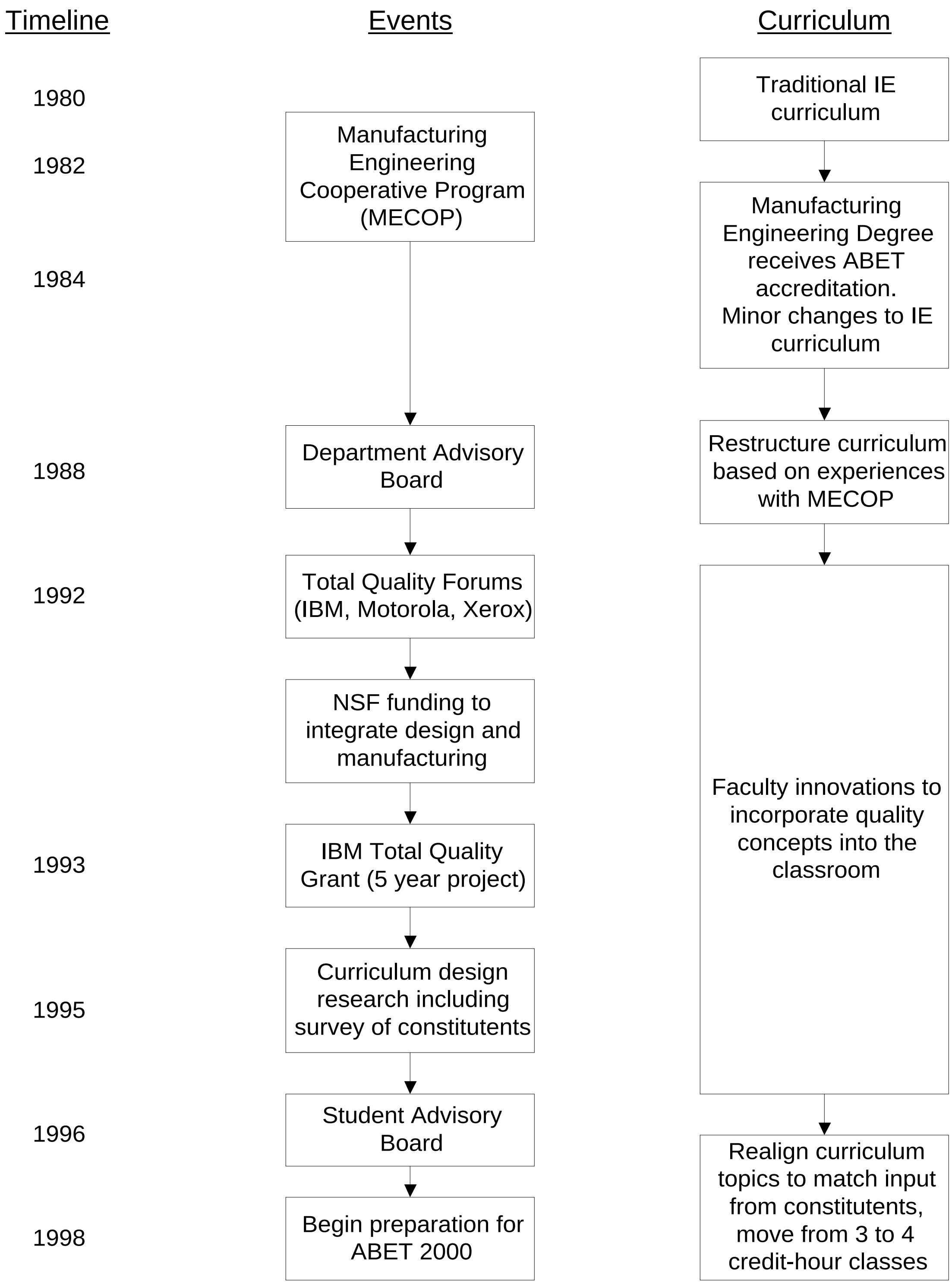

Figure 1. Timeline of Events and Curriculum Changes

The program has since been expanded to include all but one of OSU's engineering departments plus the Management and Information Systems department in the College of Business. MECOP currently consists of 48 companies and placed 225 students on assignment in 1997/98. Participating companies have at least one representative on the MECOP board, which has responsibility for the implementation of the program. MECOP graduates who responded to a 1995 survey were extremely complimentary to the program. The following comment from a 1993 graduate was typical: "The MECOP program was a highly beneficial educational experience".

Exposure to Quality Principles

The Total Quality Forums were really the first significant exposure that faculty had to changes that had been occurring in industrial organizations such as IBM, Xerox and Motorola. Top management representatives came not to tell us what to do, but to communicate the extent of the changes their organizations were experiencing and the motivation for making these changes. From these interactive discussions, we heard what they had learned, both good and bad, and what primary benefits resulted from the experiences.

Significant economic growth in the high technology sector has occurred in the Portland metropolitan area. Companies in this sector have been at the forefront of incorporating quality management principles in their organizations and many are active participants on the MECOP board. These organizations have been a tremendous resource in providing guest lecturers and a wide array of complex, real-world student projects. Local experts have taught key sections in our electronics manufacturing, facilities and project management courses and have assisted students in the development of meaningful capstone design projects. Through all of this, IME faculty and students obtain valuable exposure to industrial practice.

Faculty Receptive to Ideas

While necessary and valuable, exposure to new ideas is not enough. An academic environment must be created such that faculty members must be receptive to ideas and be prepared to implement changes. Many of our faculty had industrial experience either prior to coming to OSU or have gained experience from summer work or faculty internships. This background has enhanced their understanding of the importance of staying current and developed an appreciation of why the success of our undergraduate program is so important to the future growth of the department.

A number of faculty formed quality improvement teaching teams that met regularly to discuss how to improve both the teaching and learning process and to incorporate many non-traditional pedagogical techniques. Faculty initially utilized some of the various quality improvement tools such as gaining feedback during a course through the application of assessment techniques identified by Angelo and Cross[11]. Several faculty used student quality improvement teams that met weekly with a facilitator to discuss how the class was going and to provide specific suggestions for improvement. Faculty members also participated in various seminars featuring topics such as incorporating active learning exercises[12] and the integration of writing throughout the curriculum.

It is appropriate to recognize that not only were faculty receptive to new ideas but that they went through the hard work to incorporate the changes and introduce them to their classroom activities.

Encouragement by Department and College Administration

Departmental and college administrators actively participated throughout this entire process. Leadership personnel were quite active through industry contacts such as the Total Quality Forum and various advisory boards. Several of the ideas that faculty incorporated were created and developed through the participation of the administrators. The funds that we received through the IBM Total Quality Partnership were leveraged to implement curriculum improvement ideas from faculty and administration. Projects included the development of standard modules to be used in all engineering orientation classes and the development of an interdisciplinary, two-term senior project class that was focused on new product design and involved students from various engineering programs and the College of Business. Curriculum research was directed by the associate dean and partially funded through the IBM grant[13].

Conclusion

It is often difficult to understand and recognize the extent of the change when you are in the middle of the system undergoing the change. You are concerned about trying to implement your personal components and often lose sight on how the entire system is reacting to multiple activities. This is a common reason why many companies put charts and graphs on the wall so employees can see how the organization is performing.

In our case, the “aha” came when we displayed examples of course material from the revised curriculum. It was only then that we started to appreciate how successful we had been at building a much more innovative program than existed only a few years previous. That success was the result of ideas and hard work from faculty, administration, employers and alumni. Reflecting back on the changes and the process to achieve them has helped us to prepare for the new accreditation requirements contained in ABET 2000.

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JOHN E. SHEA, Ph.D., is an Assistant Professor in Industrial and Manufacturing Engineering at Oregon State University. He has an undergraduate and a graduate degree in electrical engineering, an MBA and a Ph.D. in Industrial Engineering. Prior to joining the faculty at OSU, he held positions at Chaminade University and Hewlett-Packard.

TOM M. WEST, Ph.D., PE is Professor Emeritus in Industrial and Manufacturing Engineering at Oregon State University. Prior to joining the faculty at OSU, he held positions with the University of Tennessee, Monsanto Chemicals, and IBM. He is a former Vice-President of the Institute of Industrial Engineers and a Fellow of the Society of Manufacturing Engineers.