Abstract

Our integrated approach to engineering management is innovative because it offers elective options that are tailored to the students’ career goals. It focuses on the broader issues and globalization, and it has partnerships with local industry. A graduate certificate is also offered. Class projects are assigned that use the course principles to solve "real world" problems in the students’ work environment. Students work both individually and in multi-disciplinary teams.

I. Introduction

In 1991, the National Research Council stated that "U.S. industry’s period of world dominance in product design, manufacturing innovation, process engineering, productivity and market share has ended" [1]. This could have been a reaction to the sluggish economy, the downsizing of engineers and reduced funding for aerospace/defense and research in the US. However, in addressing improvements necessary to develop new national goals, the Committee on Science, Engineering and Public Policy recommended that graduate education of scientists and engineers should be broader, more flexible and cross-functional [2].

For the last 5 years, Loyola Marymount University (LMU) has addressed the above challenges in graduate education by forming a cross-disciplinary engineering-business program. The Colleges of Science & Engineering and Business Administration have combined their efforts to offer an M.S. degree in Engineering and Production Management (EAPM). The mission of the program is to educate engineers in the manufacturing and management of globally competitive products for the 21st Century. It is a part-time, practice-oriented master’s degree that is administered by the College of Science & Engineering. All of our students work full-time in local industry and attend classes in the evening. Our graduate program currently has over 50 students in it. Because our program has both breadth and flexibility, it contains several innovative concepts.

The EAPM program was not intended to be another clone of the engineering management programs [3]. It was thoroughly researched and planned in order to have an integrated curriculum that satisfied the current and future needs of industry in Southern California. The purpose of this paper is three-fold: to determine which universities offer integrated curricula, to present the need for our program, and to discuss how our program is innovative.

II. Integrated Engineering Curricula
A. Hypothesis. Engineering/technology management graduate programs are one of the fastest growing programs world-wide. Their growth rate since 1990 has been 8.3% per year [3]. Most of these programs either consist of engineering courses that emphasize management techniques or business courses that emphasize the management of technology. Although several universities offer such programs, few universities offer a focused and integrated curriculum between two or more colleges [4].

An example of an integrated curriculum is having both engineering and business courses within the same program. It also involves team teaching courses with engineering and business instructors. Based upon the author’s discussion with others, smaller universities offer more innovative strategies in higher education [5]. However, this is more anecdotal without any statistical evidence to verify the hypothesis.

The challenge is to prove that smaller universities in the U.S. offer more integrated engineering and business curricula than larger universities. This was almost an insurmountable task. How do you find such data without performing a survey?

B. Verification. The first attempt to collect this data was performed through the ASEE’s graduate engineering statistics [6] and profiles of engineering schools [7]. Based on the author’s knowledge of integrated programs throughout the U.S., it soon became apparent that these data were either inaccurate and needed to be up-dated. In addition, the ASEE surveys used to generate these data did not request interdisciplinary program information.

The second attempt to generate this data came from an internet search. A web site was used [8] to find out about university curricula. This turned out to be very time consuming and did not yield relevant information. It was thought that the best way to approach the hypothesis would be to focus on a fewer number ~200 public/private universities in the western states (defined by the Carnegie Foundation for the Advancement of Teaching) [9]. The approach was to identify the universities [10]; go to their web sites and compare the regional universities with the national universities. However, even this proved to be an overwhelming task, because many of their home pages were either not current or were not specific about their programs.

Due the difficulty in obtaining this information, a third approach was used which provided an indication of the number of innovative, integrated programs in universities. The indicator that was used was the number of universities that were members of the National Collegiate Inventors and Innovation Alliance (NCIIA). The goal of this NCIIA is to promote creativity, excellence and entrepreneurship among universities through engineering and business collaborative teams [11]. There were 78 NCIIA member universities across the U.S., and these universities were used as a rough measure of the number of universities that offer integrated curricula. The total institutional enrollment of each university was obtained [10], and the data were grouped into 3 categories: small enrollment, <8,000 students; medium enrollment, 8,000 - 16,000 students, and large enrollment, >16,000 students. Examples of universities with small, medium and large enrollments universities, respectively, were Dartmouth with 5,300 students, Stanford University with 13,800, and Northwestern University with 17,700 students. A histogram of the frequency vs. the enrollment size of the university is shown in Figure 1.
C. Rationale. Figure 1 shows that the number of small universities are almost twice that of large universities and about four times larger than that of medium size universities. These results qualitatively verify the hypothesis that the degree of innovation is inversely proportional to the size of the university. These results are not surprising, since larger universities place more emphasis on Ph.D. research and receive federal funding for their research endeavors. The small universities place more emphasis on teaching and developing relevant educational programs.

Another way to viewing these results is to use the analogy that was developed by the British aerospace industry: "the amount of innovation is inversely proportional to the size of your budget" [12]. The rationale behind this is faculty at large universities usually have large budgets and thus have a lower motivation to be creative in their graduate programs. On the other hand, the faculty at smaller universities usually have smaller budgets and must compensate for this by being more innovative in their programs to better serve the needs of their constituents.

III. The Need for Integration

A. Job Supply and Demand. The demand for engineering management jobs in manufacturing was sampled in Los Angeles County to evaluate the market niche for our EAPM Program. In 1994, during a sluggish manufacturing economy, it was predicted from 1995 to 2005 that the job demand would exceed the job supply by a factor of > 2 [13]. In light of the recent upsurge in the manufacturing sector (~3% growth in 1998), the predicted job supply and demand was re-evaluated. The data were gathered from the classified ads of the Los Angeles Times, Sunday edition [14].

The number of jobs in the classified ads was used as an indicator of the job demand in the high technology categories: engineering (manufacturing option), manufacturing, production, quality and management (technical). The jobs were mainly in aerospace/defense and commercial manufacturing. From the sampling, the job demand was estimated to range from 35-70 new jobs per week over a 6 month period. This translated into 1820-3640 new jobs per year, or 12,740-25,480 new jobs from 1998 to 2005, assuming the rate of job creation was the same over time period. This current number of new jobs was about 4 times more than in 1994.
Assuming that 150 students/year are supplied to the job market from the technology management programs in Los Angeles (15 students/year per university x 10 universities), the current job demand above will far exceed the supply of students. If the number of university programs in Los Angeles increases from 10 to 15 by the year 2005, assuming 8.3% per year growth [3], the supply of graduating students is expected to be 225 by the year 2005. Using a worst case scenario for the current rate of job growth over the next 7 years, the job demand is predicted to exceed the job supply of graduating students by a factor of ~8. These rough estimates indicate that the demand for our EAPM graduate students is very strong, and this is expected to continue to 2005.

B. Industry’s Needs. Since our constituents are private industry, we surveyed industry’s needs and designed the curriculum around those needs. Many of the desired qualities of our EAPM program were related to manufacturing, because Southern California has the second largest manufacturing center in the U.S.

In 1990, a detailed survey was conducted with over 50 top executives from aerospace/defense and commercial manufacturing companies [13]. Their three strongest needs were: (1) an interdisciplinary engineering and business curriculum, (2) 30-36 semester-hour master’s program, and (3) relevance to manufacturing and total quality.

In the Fall of 1994, another survey was conducted to again research industry’s needs [13]. Over twenty (20) manufacturing companies (both large and small, aerospace and commercial) responded to the survey. Their greatest need was educating engineers both in the manufacturing of profitable products and in concurrent engineering.

During 1997-98, focus group discussions were conducted with our Industrial Advisory Council, which is made up of 8 industrial executives from aerospace and commercial companies. They advise the EAPM program on current needs and new trends in technology, business and management. From brainstorming sessions, the critical skills that were considered important were: (1) global outsourcing and virtual teaming, (2) project management, and (3) entrepreneurship.

The above attributes are important because engineers in the 21st Century must be self navigating entrepreneurs, who are capable of taking risks, being change agents, being continuous learners, and being collaborative problem solvers with strong communication and computer skills [15]. Other futurists have indicated that the most important needs are creative thinking, information sharing, and rapid product development [16]. It has been pointed out that many of these skills are difficult to cultivate in a traditional university environment, because universities tend to be risk-adverse, not very creative, and move too slowly for the rapidly changing global economy [17]. The intent of our EAPM graduate program is to change this image.

IV. Innovative Concepts
A. Flexible Curriculum. The specific goals to accomplish our constituents’ needs are (1) promoting the manufacturing of profitable, robust products through teamwork, (2) teaching engineers to be modern managers in a global economy, and (3) developing a flexible curriculum that changes to meet the needs of industry. The EAPM master’s program emphasizes a broad curriculum in engineering, business and total quality, as previously described [13]. Any current changes to the program appear on our web site at http://www.lmu.edu.

There are 8 core courses in our curriculum, 2 electives plus a capstone project/thesis course, which yields 11 courses (or 33 semester-hours) for the M.S. degree. Within the core curriculum, two courses are taught by the business school and one course is co-taught by engineering and business [18]. The students can select their electives in manufacturing, project management, systems engineering, or other graduate courses in engineering or computer science. During the 1999-2000 academic year, elective courses in entrepreneurship will be co-taught with business, and a course in engineering management & leadership will be added to the EAPM curriculum.

In addition, students have the option of substituting two electives for the capstone project/thesis course, which will give a total of 12 courses (or 36 semester-hours) to complete the master’s degree. If students decide to take this path, 1/3 of their courses will be electives, which gives them the flexibility of designing their curriculum around their educational background, work experience and career goals. Due to the high degree of interaction between the EAPM and the MBA programs, a EAPM/MBA dual degree is currently being planned, and this is expected to be in place by the 1999 Fall semester.

B. Global Perspective. The strength of our program is that it focuses on the broader issues that affect the U.S. economy and competitiveness, like producing technical products better, faster and cheaper. We expect that our students will be continuous learners, communicators, and project integrators for the 21st Century, where rapid change due to globalization will take place.

In order to prepare our students for their future roles, throughout our curriculum, we emphasize the total quality principles, customer satisfaction, design-to-cost philosophy, and quickly launching products on the market to enhance their profitability. We foster creative thinking and problem solving skills, being flexible agents of change, and making logical decisions when faced with risk and uncertainty. These skills are applied in our 8 core courses: computer-aided engineering applications, statistics for quality, production engineering & total quality, operations analysis &

decision systems, new product design & development, business law, managerial & financial accounting, and engineering ethics.

A course in international studies is scheduled to be taught in the 1998-99 academic year, which will address globalization. The course goal is to compare lean manufacturing in U.S. companies with those in Germany. Several high technology companies will be visited, and case studies will be formulated and benchmarked against their counterparts in the U.S. The course will be taught in Bonn, Germany by a faculty member who is an international expert in total quality.
Globalization is also being addressed by preparing our students for global outsourcing of subassemblies of complex products. For example, during the 1998 ASEE conference in Seattle, the author visited a Boeing plant and discovered that ~80% of the subassemblies in their aircraft are globally outsourced and brought into their plant for just-in-time assembly [19]. In the EAPM program, our students are exposed to making decisions on "make-buy" criteria, activity-based costing that links the cost driver to the manufacturing process, and virtual teaming where students interact with their team on-line, without physically being co-located in the same place at the same time. Students are also introduced to international marketing in our course on new product design & development.

C. Graduate Certificate Program. In 1998-99 academic year, a graduate certificate in Total Quality Engineering was started as a spin-off to the EAPM master's program. The purpose of the certificate was to allow students to take three introductory courses in the EAPM program without being accepted for admission into the master's program. The courses are production engineering and total quality, statistics for quality, and computer-aided engineering applications. If the student meets the grade requirements and decides to continue in the EAPM program, the courses will apply toward the master's degree. If not, then the student can terminate his/her studies and receive the certificate. This graduate certificate has also been used as a "consolation prize" for those students who enter the master's program but can't meet the grade requirements.

D. Industrial Partnerships. We currently have twenty industrial partners that interact with the EAPM program, i.e., Hughes, Raytheon, Boeing, TRW, Northrop-Grumman, Allied-Signal, Teradyne, ITT-Gilfillon, Jet Propulsion Laboratory, Proctor and Gamble, Johns Manville, Gillette, Fairchild Fasteners, Z-Tronics, Mobil Oil Co., Flow Serve, Ultraviolet Devices inc., Aerospace Co., Cushion Cut, and Xerox. These companies have sent their employees to our graduate program. The most important interaction has been the establishment of our Industrial Advisory Council in 1994, which is made up of industrial executives who advise our program on their current and future needs.

Small companies have also been involved with conceiving industrial projects for our classes. Here students assist start-up companies in the planning, design and development of real products using the principles of the course. This has been described as the "teaching factory" approach for problem-based learning, where students apply lessons learned to solve real world problems [20]. Some of our industrial partners are asked to evaluate the class projects, provide field trips to their plants, and deliver guest lectures to our students.

In addition, the capstone project/thesis course has enabled students to solve an engineering/management problem in their work environment that applies the principles learned in the EAPM program. This is a win-win-win situation. It is a win for the company because prior projects have developed new products and saved the companies > 25% on their existing projects. It is a win for the students because they have all received substantial salary increases upon completing the course and have positioned themselves for future promotions. It is a win for EAPM program because the project/thesis course has reinforced the philosophy of continuous learning.
Over the last few years, the EAPM program has developed a strong relationship with Hughes Space and Communications. Since they supply about 1/3 of our EAPM students, LMU has started teaching selected courses on-site at Hughes. We have an endorsement from the corporate vice president of Hughes stating: "LMU’s Engineering and Production Management graduate program provides an integrated approach to educate engineers in the manufacturing of globally competitive products."

E. Working in Project Teams. In every course throughout our curriculum, the students have both individual and collaborative projects that relate to the principles of the course. For example, in one case, the engineering students worked as a team on a joint research project with the business students to develop a new pressurized container for preserving fruits and vegetables [20]. Here the engineering students developed a preliminary design and a manufacturing plan, and the business students developed a business plan for the project. In another example, our course in new product design and development has engineering and business students working together on multi-disciplinary teams to jointly conduct marketing research, design products, and build prototypes of new commercial products. In this case, the teams develop technology and marketing plans and perform a payback analysis on their products [18]. Frequently we require that the students apply the course principles to solving industrial problems in their own workplace; then they orally discuss their results in the classroom so that others can ask questions and benefit from the discussions.

F. Faculty with Industrial Experience. Our course instructors are either full-time or part-time faculty. They have engineering backgrounds and have distinguished themselves as managers, consultants or entrepreneurs. It has been found that most academicians who lack industrial experience do not have the motivation, experience and skills to integrate engineering and business [4]. In all cases, our faculty has extensive (~10 years) industrial experience and prior teaching experience. Since most traditional Ph.D. engineers tend to be narrowly focused in their disciplines, we hire the best qualified instructors with broad engineering and business expertise regardless of their educational background. About one-half of our instructors have Ph.D.’s in engineering; one-quarter have M.S. degrees, and one-quarter have B.S. degrees in engineering. In addition, many of our instructors have MBA degrees. All of our instructors are committed to integrating both technical and business skills into their courses.

V. Conclusions

Our Engineering and Production Management program has both breadth and flexibility. It addresses the challenges proposed by the Committee on Science, Engineering and Public Policy concerning the cross-functional graduate education of engineers. The demand for our graduates in the form of new jobs in Southern California is predicted to be very strong through 2005. Through focus group discussions, the most current needs of industry are students that are educated in global outsourcing and virtual teaming, project management, and entrepreneurship. Few universities offer a focused, integrated curriculum. The results indicate the most innovative programs originate from smaller universities. The larger, nationally ranked universities concentrate more on research and less on multi-disciplinary programs. Our approach to graduate education links engineering with business and total quality. The EAPM is innovative because ~1/3 of the curriculum has elective options in manufacturing, systems engineering, project management and entrepreneurship, and it focuses on the broad issues of the global economy. It offers a graduate certificate in Total Quality Engineering and has partnerships with local industry. Class projects are assigned that use the course principles to solve "real world" problems in the students’ work environment. Students work both
individually and in multi-disciplinary product teams. Our faculty is selected based upon their industrial background and teaching experience.

Bibliography
2. Committee on Science, Engineering and Public Policy, Reshaping the Graduate Education of Scientists and Engineers, National Academy of Sciences, National Academy of Engineering and Institute of Medicine, National Academy Press, Washington, DC, 1993.
11. National Collegiate Inventors and Innovators Alliance (NCIIA), Hampshire College, Amherst, MA; (413) 559-5318; http://hampshire.edu/nciia.

MEL I. MENDELSON
Received his B.S. from UC Berkeley, his M.S. and Ph.D. from Northwestern University all in materials science and engineering. He has 24 years of industrial experience. In 1994, he became Director of the Engineering and Production Management graduate program and Associate Professor of Mechanical Engineering at LMU in Los Angeles. His interests are in materials processing and manufacturing, total quality and failure analysis.