The Pedagogic and Technological Evolution of a Manufacturing Systems Engineering (MSE) Graduate Program

Keith M. Gardiner
Lehigh University, Center for Manufacturing Systems Engineering
200 West Packer Avenue, Bethlehem, PA 18015
610-758-5070  kg03@Lehigh.edu

Abstract - Graduate programs for a cross-disciplinary MS degree in Manufacturing Systems Engineering are in their twenty-fifth year since being stimulated by an innovative request for proposals (RFP) by the IBM Corporation. The RFP called for solutions to perceived gaps in engineering education. There is a continuing need for engineering professionals to gain appreciation of business issues, the importance of interpersonal communication, teamwork, information technologies and globalization. The Lehigh program, one of the five US proposals funded, has evolved both pedagogically and technologically since welcoming the first students in January, 1984. The program has migrated from dealing with twenty to thirty full-time on-campus students sent by their industry employers to catering for similar numbers of partial-release students and in the last decade to students that participate remotely. Classes are delivered by satellite and are available on-line; students employ a ‘phone bridge to join ‘live’ classroom discussions and to support their own presentations or those of their team colleagues. Digitized videos of class proceedings are available on customized Blackboard™ sites. Blogs, Discussion Board assignments and analysis of leading-edge technical releases empower the students of this ‘classroom factory’ as they undertake research and share their industry experiences.

Index Terms - Distance education, manufacturing systems, graduate program, cross-disciplinary.

INTRODUCTION AND HISTORY

Almost thirty years ago the IBM Corporation experienced intermittent delays and schedule slippages in the introduction of several new products. The ‘manufacturing’ community was often alleged to be responsible. Task force investigations attributed the perceived problems to deficiencies in the communication and strategic business skills of the engineers engaged in manufacturing-related activities. The creation of an ‘internal IBM university program’ was recommended and in mid-1981 the IBM Manufacturing Technology Institute (MTI) under the leadership of Samuel B. Korin was established on 42nd Street in Manhattan [1]. The Institute was charged to improve the business, communication, logistics, management and teamwork abilities and advanced technological awareness of mature graduate engineers that were already experienced in the IBM workplace. The first ten week residential program welcomed 45 IBM employees from manufacturing sites around the world as students in September, 1981. This intensive program was offered three times a year, with two week programs focused on special advanced technology-related topics the remainder of the year. Faculty were engineers and managers ‘drafted’ from various manufacturing sites to serve this Corporate entity. The initial programs received wide acclaim and as result of increasing demand a parallel operation was created in Belgium.

Two years after MTI’s inception it was recognized that the ten-week operations in Belgium and New York did not have capacity to satisfy the foreseen demand for widening the abilities and horizons of existing engineers, and also for engineers newly in the workplace. Engineering curricula being offered at that time, even when complemented by a subsequent MBA were not providing a suitable range of skills; the need to develop a cadre of ‘Manufacturing Systems Engineers’ was postulated. IBM circulated a request for proposals (RFP) for Manufacturing Systems Engineering graduate programs in 1983 with the backing of $10 million in funding plus equipment. This was preceded by a widely attended meeting of deans and other university representatives in New York to hear presentations and discuss the MTI curriculum and objectives [1]. The ‘fine print’ of the RFP called for cross-disciplinary proposals that embraced business and engineering and did not originate from a single department. Ultimately 110 responses were received. Funding was awarded to Georgia Tech., RPI, Stanford, Wisconsin-Madison, and Lehigh. The Lehigh University MS in Manufacturing Systems Engineering Program welcomed the first students to campus in January 1984 and included faculty from several departments of the colleges of both business and engineering as contributors [2].

The Lehigh Program commenced in January, successful students graduated the following January and returned to their IBM sites worldwide. Several other companies also took advantage of the opportunity and seconded employees to Lehigh for one year in residence customarily on full pay, per diem, with family relocation and full tuition. The
program consisted of thirty credits including a research project; specially created core courses were developed by faculty in both colleges. Now the program is administered by the Center for Manufacturing Systems Engineering and essentially ‘borrows’ faculty from a wide variety of departments in all the three major colleges at Lehigh. Initially, there was an active summer semester with a one week tour of industry. Further developments included a seminar program and an annual conference with industry for the management of the supporting enterprises. Companies that joined IBM in sending employees to the program included AMP, AT&T, Boeing, H-P, IBM, I-R, Ford/Visteon and others. In 1985 the program won the LEAD award from the Society of Manufacturing Engineers (Leadership and Excellence in the Application and Development of Enterprise-wide Integrated Manufacturing).

As result of an RFP from the AT&T Foundation funding became available to subsidize a parallel two-year part-time offering of the program. This commenced in 1991 and consisted of Thursday evening classes and all-day Friday and enabled the participation of employees from enterprises within commuting distance of Lehigh (Baltimore, Harrisburg, Philadelphia region etc.). Some lectures were shared by making adjustments to mesh the schedules of the two cohorts. GM provided the next developmental opportunity with funding of a focused course dealing with agility and globalization to be delivered using distance technologies (initially VHS tapes). This course was introduced as an MSE elective in 1997. In later years GM registered up to 70 employees in this course every fall at sites between Canada and Mexico; it was a mandatory component of several of their M.S. programs with other institutions (e.g. Kettering, Michigan and Purdue). GM participation ceased abruptly after the fall class in 2004 as the US automotive sector reorganized. A subsequent proposal to GM for the whole program was unacceptable as result GM wishing to reduce the numbers of educational providers and a requirement for international collaborations.

Meanwhile in response to the guidance of an Industrial Advisory Board courses were continually up-graded and augmented. As all these things were happening the world was changing and industrial competition became more intense and global. ‘Down-sizing,’ ‘lean,’ ‘Total Quality Management,’ ‘Six Sigma,’ and the elimination of waste received serious industrial attention. The enrollments of part-time and satellite (distance) students increased, but full-time on campus students diminished in numbers and virtually ceased by 2001. The curriculum was adjusted to make a mandatory practical laboratory design course an elective. The program then became wholly available using distance technologies in fall 2002. There are occasional applications from self-funded potential students from Asia, Central and South America but today, in the main, MS in MSE candidates are based nationwide with concentrations in the east and northeast. Students from many states are currently enrolled including California, Delaware, Maryland, Massachusetts, Michigan, New Jersey, New Mexico, Oregon, Pennsylvania, North and South Carolina, Texas and Virginia (and Mexico). The number of students registered for the three MSE courses offered in spring ’08 was seventy.

**PEDAGOGY**

The eighties were a period when US manufacturing and engineering were being pilloried by the media and politicians for many of the problems of the modern world, and Asian competition in particular. Engineers were largely regarded as ‘nerds with pocket protectors that were unable to communicate effectively or understand business issues.’[3] Communication, acceptance of mutual dependencies and teamwork were emphasized ‘experientially’ at IBM’s MTI, and most effectively in nearly every core course in the Lehigh MSE Program. Courses that had been specially developed for the annual MSE cohorts began to be recognized as having value within other Lehigh MS programs; MSE students were welcomed in elective courses because of their abilities, real-world contributions and maturity. Use of teams in engineering classes has now diffused into first year ‘Introduction to Engineering Practice,’ and is commonplace at all levels across campus (as it is also in our school systems from middle school on) [4][5]. Simultaneously, the increasing use of Information Technology accelerated improvements in the communication and presentation skills of many students. There has also been an increasing cross-fertilization bringing business and management issues before engineering students, and vice versa for business students. There is greater attention ‘campus-wide’ to cultural issues, diversity, economics and matters affected by globalization which were all topics in early MSE classes. Thus, it can be claimed that the IBM initiative of 1983 really did give added and effective impetus to curricula development.

‘Technology, Operations and Competitive Strategy,’ was the first MSE-developed course to be adopted and cross-listed by the College of Business (CBE). In 1998 at the behest of the MSE Industrial Advisory Board the development of a course dealing with ‘International Supply Chain Management’ was undertaken by faculty in CBE and funded by the Center for Manufacturing Systems Engineering. This course has been delivered successfully alternate years as an elective offering in the MSE Program, and has subsequently been complemented and ‘morphed’ into a CBE certificate program. A course initially developed with the aim of introducing MSE students to the possibilities of using mathematical methods for forecasting and resource allocation more recently found application as an introductory course in Operational Research (OR). An Integrated Product Development Program and the several off-shoots undoubtedly owe much to the stimulus of the initial IBM MSE template. Many courses developed as a part of the MSE Program are also utilized as electives by students in other graduate programs. For curriculum details see the web site: http://www.lehigh.edu/~inmse/gradprogram/
‘Manufacturing’ and ‘Jobs’ receive appreciable attention and emphasis and have close association with national prosperity and global economic trends. These topics together with workforce preparation continue to receive attention. The National Research Council of the National Academy of Engineering (NAE) initiated a study with a report published in 1998 [6]. Additionally there was a Society of Manufacturing Engineers (SME) study in 1999 [7] that captured findings from a series of conferences and publications on manufacturing education [8][9]. These studies uniformly called for development of broader curricula with greater cross-disciplinary emphasis, and also requested greater accommodation to unforeseen advanced technologies. Manufacturing began to be perceived increasingly as a ‘systems’ activity requiring knowledge of the specific process technologies, the chemistry and the physics of atomic, molecular and physical phenomena together with awareness of organizational behavior, business, management and the manifold skills required to lead operations in a global multicultural environment. The NAE 2020 Vision even recommended the inclusion of anthropology as one of many topics that merited inclusion in a 21st century engineering curricula [6].

These industry changes and the associated curricula concerns have become global. MSE programs, supported by IBM and others, were successfully spawned in Europe and Asia. The international Intelligent Manufacturing Systems (IMS) initiative also supported a ‘Global Education for Manufacturing’ curriculum development proposal that has received wide discussion (GEM) [10][11][12][13]. This latter project developed a curriculum framework and demonstration samples were put together, but the ‘dream’ of intercontinental collaborations with delivery of courses and even degree programs has, so far, in this area not been shown to be feasible. It appears that even though industry has capability, and even a need to accept collaboration and interdependencies this is inimical for the academic community who are more accustomed to instructor autonomy and individual control. These attitudes make the achievement of ‘integration’ across a single campus a noteworthy accomplishment, to achieve this successfully across oceans still lies in the future.

The SME study enumerated the ‘Critical Needs for Future Engineering Professionals’ as follows [7]:

Highly Critical:
Business knowledge/skills; Project management; Communication – written and oral/listening; International perspective.

Other Topics Needing Emphasis:
 Manufacturing process science; Process control; Systems engineering design & integration; Product/process design; Engineering fundamentals.

Currently the Lehigh campus has satellite transmission capability from three classrooms. Cameras possess remote controls for zooming and rotation, and there at least four in each classroom. One to cover the instructor, two for students and one overhead above the instructor’s desk/podium for display of pages of magazines, textbooks, other graphic media or hardware. There are further cameras internal to the broadcast system that take images directly from the classroom computer for Power Point files, spreadsheets or clips from the internet, or a 2x2 slide projector (now rarely used). There are large monitors to the left and right of the instructor, one linked to the computer with touch-screen control capability, and the other shows the transmitted signal. The camera at the rear of the classroom can be used for views of the touch-screen and the instructor. Use of a chroma-key is an available alternative, here there is a green backing allowing the instructor to appear virtually in front of the picture ‘weatherman style.’ If the instructor chooses it is also possible to employ a talking-head view in the corner of the chart or picture being transmitted. This facility is rarely employed because of the need to stay in the ‘box’ and the graphics restrictions. Faculty involved with distance education almost certainly have to prepare more comprehensively than for traditional chalk-on-board in a regular on-campus class, they also must participate actively as directors, producers and as the ‘talent’ for the show that is broadcast.

Currently classes are delivered by satellite and are available on-line; students are able to employ a ‘phone bridge to join ‘live’ classroom discussions and to support their own presentations or those of their team colleagues. Alternately, when necessary due to exigencies of business or time zone incompatibilities Power Point files with added voiceover are employed. Meanwhile, digitized videos of class proceedings are made available within four hours on customized Blackboard™ sites. Additionally, real-time streaming video can be accessed by a limited number of students. Blogs, Discussion Board assignments and analysis of leading-edge technical releases engage the students of the ‘classroom factory’ in on-going continuing education as they undertake research and share their industry experiences using collaborative wikis. In many MSE courses students are deployed in virtual teams to report on assignments that are presented before the whole class. There is capability for teams with students in remote locations to book conference calls through the Lehigh exchange.

Files and materials used by instructors are customarily posted onto the course web site several hours before class so that students have access to everything ahead of time. The availability of Power Point files and handouts is important so that students can view originals without the resolution degradation that inevitably accompanies analog satellite transmission. Satellite downlinks to remote classrooms have been established at a number of community colleges and at the locations of many company clients.
Internet 2 is used at Lehigh to enable remote students in Materials Science to operate electron microscopes and share courses collaboratively with other campuses. Several courses in the Lehigh MBA program require campus visits and also use two-way conferencing systems such as Centra and Elluminate. These technologies may be adopted by the MSE Program as they become more pervasive; campus visits, on the other hand, would be difficult to schedule for the current MSE cohort.

Although the face-to-face lab. and office interactions with the full and part-time students of the eighties and nineties have disappeared, there are numerous e-mails and ‘phone calls. All current MSE students are actively engaged with day-to-day problems in industry as their full-time jobs. In many cases one of these tasks may also afford a source for their required MSE research project. Their average ages and levels of seniority have increased. They communicate and work in diverse teams coalescing insights from pharmaceutical industries to the attention of engineers working on engineering problems in a wide variety of contrasting realms. They also impart valuable lessons to the less experienced students on-campus attending MSE courses as electives.

CUSTOMER SATISFACTION

A survey was sent out to students currently taking MSE courses seeking comments on their experiences with the satellite system, the asynchronous aspects, Blackboard™, working on ‘virtual’ teams with individuals that they have never met. They were also asked to comment on any differences from their prior baccalaureate education.

Several observations are worth sharing here. Notably, mature students, pulled in many directions, enjoy the convenience and portability of distance education. Families, children, full-time employment, business travel, and classes all contribute to very busy schedules. The ability to access MSE classes on-line from a computer in any location allows a student to keep up with lectures, and communicate with professors and classmates without interruption to business schedules, and at a time that is most convenient for the individual. “24 hours a day from anywhere, you can make your own schedule: I have three small children and without on-line study I would not have been able to pursue a Masters degree,” comments one happy customer. Another student remarks, “I am married with two teenage children and work full-time, I can view courses when it is convenient for me.” Another feature students’ appreciate is the ability to review class lecture archives, “…if you need to review a concept, or … the entire class …it is available 24/7.” An individual working full-time shift work comments on his/her appreciation of the flexibility of on-line class access.

Communications through the class web site Discussion Board and collaboration in team projects are valued as key learning tools by students. “… The discussion groups … allow us to discuss relevant and timely information. This keeps the class fresh and interesting,” comments one enthusiast. Other students value their colleagues’ contributions: “…the discussion board is a great interaction tool. … since almost all the students have different backgrounds, you can see the same concepts applied in different industries, and expressed from different points of view,” and another remarks, “Diversity of perspectives lets you know what is specific to your organization and what is similar across different business environments.” One student explains team project experiences, “I have had nothing but good experiences working with other individuals for team projects, same city or across the country, and the Blackboard System™ eases everything.”

When asked to compare and contrast their graduate studies experiences with previous educational experiences, students’ comments were positive. “I miss the hands-on lab aspect of my undergraduate work, but I feel like I am part of the school even though I have never stepped on campus,” writes one. Another student comments that his communication skills have improved, “…since English is not my native language and by pursuing a Masters degree, I am exposed to a lot of information that I have to read, write and speak, that I consider to be key to improvement of my communication skills.” One student believes that faculty are “more enthusiastic and cooperative,” in his/her graduate experience. Another comment relates to the practicality of the graduate experience, “Lehigh is much more practice-oriented with real life examples, less theory, more applied, etc.”

These comments are from a cross-section of students from a variety of MS and certificate programs in addition to the MS in MSE (IE, QE, Management Science, etc.) and reflect their varied backgrounds and levels of seniority. This is especially evident in a few comments about teamwork where a desire was expressed for imposed structures; in fact, teams in MSE courses are structured with the subsidiary aim of mixing disciplines, ethnicities, genders, and industries. On-campus students with little or no industrial experience find this a valuable although difficult challenge. Other comments, not shown, mentioned a few technical reception problems that were generally handled promptly and well, and occasionally originated at the receiving end.

SUMMARY AND FUTURE

The Lehigh MS in MSE Program has adapted and evolved from a full-time on-campus offering enabling resident students to acquire their degrees in one calendar year, through a part-time, or partial-release version taking two years into a flexible wholly distance offering. The curriculum, pedagogy and delivery systems have changed remarkably. The program started in 1984 using chalk-on-board with overhead and 2x2 slide projectors; next was a specially adapted ‘executive’ classroom ‘theater’ with individual upholstered seating, one whole wall as a white board and monitors for showing VHS tapes. The next stages came quickly with video equipped classrooms, computer projection systems, and the inevitable Power Point. The
titles of courses have changed slightly and new topics have been introduced. The content remains focused on current and future manufacturing technologies, practices, processes and their integration with the business and management challenges of the present century. The students in our classrooms by describing their own problems, their workplace experiences and by contributing electronically bring appreciable knowledge and maturity for sharing with their colleagues. In total, 364 Lehigh alumni have been awarded MS in MSE degrees and are making contributions to manufacturing industries globally.

It has not been possible to undertake a systematic survey of the effectiveness of the education. However, alumni from earlier decades are now recommending the program to their employees. Additionally linkages among alumni are gradually developing via the ‘Linked In’ networking system. Alumni are enthusiastic about keeping in touch and obviously value their Lehigh experience.

The strengths now represented by the program as result of almost a quarter century of evolution embrace all of the original IBM objectives of business, communication, logistics, management and teamwork but have been significantly augmented. Systems and the importance of effective integration receive greater emphasis today, and there are countless examples taken from current business and technology news. Globalization, sustainability, and the unavoidable conflicts between short and long range strategies, the ‘bottom-line,’ dependencies on exchange rates, energy economics and political instability must all be factored into manufacturing systems decision making. In particular, the issues of health, welfare and workforce development have become a major and global factor in the development and execution of successful manufacturing systems.

The future will undoubtedly embody continuous improvement. Already YouTube [14] clips are being posted on wikis and discussion boards and TED [15] presentations are being utilized in classes. Next developments should include transmission bandwidth increases and who knows how the expanding capabilities of cell ‘phones and BlackBerries will affect the educational milieu. Additionally explorations are planned to re-new the GEM Project and initiate collaborative ventures with other and off-shore content providers that could enrich the variety of electives available to all of our local and remote students [12][13].

ACKNOWLEDGEMENTS

The successes of the MS in MSE Program and acknowledged high quality and popularity of the courses would not have been possible over the last twenty-four years without the splendid and enthusiastic efforts of the associated faculty and the collaboration of their departments. MSE student projects have brought real industry manufacturing, research and development problems to the attention of faculty. The participation of MSE students in Lehigh courses has also strengthened overall classroom learning experiences for students in other programs. The continued support of faculty, adjuncts and students is gratefully acknowledged. The Lehigh University Distance Education administration and technicians are also deserving of thanks and congratulation.

REFERENCES
[14] YouTube accessible through www.youtube.com

Keith Gardiner retired from IBM in 1987, he is a professor of Industrial & Systems Engineering and has been director of the Lehigh Center for Manufacturing Systems Engineering and associated cross-disciplinary program since 1989. He has degrees in metallurgy from the University of Manchester, P.E. (CA); member of the SME College of Fellows and served on committees and as an officer from 1974 thru’ 2007. He is also on the Board of the 7-8th grade Future City Competition. Other affiliations include ASEE, ASME, Sigma Xi, the Engineers Club of the Lehigh Valley.