Impacts of a SME MEP Grant on Manufacturing Education at Utah State University

J. Clair Batty, John K. Gershenson, Carl G. Wood
Utah State University

Abstract

This paper describes the impacts a SME MEP Grant has had on Manufacturing Education at Utah State University. Accomplishments are summarized and obstacles described.

Prior to the grant period, industrial partnering was minimal and no departmental student or industrial advisory boards existed. The curriculum did not adequately address the 14 competency gaps identified in SME's *Manufacturing Education Plan: Phase I Report.* The Department of Mechanical and Aerospace Engineering offered an ABET accredited Manufacturing Engineering program, but did not grant a degree in Manufacturing Engineering.

Direct presentations by national SME officers to the Governor of Utah, near the beginning of the grant period, increased statewide awareness of the manufacturing program at USU. The 14 competency gaps were addressed as part of an extensive curriculum reformation. Six new manufacturing courses were developed and taught. Manufacturing applications were developed and initiated in several core mechanical engineering courses. A unique and comprehensive curriculum assessment process was developed and implemented. Industrial and student advisory boards were created and empowered.

A new Engineering Design Center was created and industrial partners more extensively participated in the design process. Student internships to manufacturing industries were facilitated. The MAE Department forged a greatly strengthened partnership with the USU College of Business.

After overcoming all state and institutional barriers, plans are in place to offer the BS degree in Manufacturing Engineering at Utah State University.

Introduction

Utah State University (USU), located in rural Cache Valley some 90 miles North of Salt Lake City, has one of the twelve ABET accredited Manufacturing Engineering programs in the country. For many years the claim was made that USU had the only accredited Manufacturing Engineering program West of the Mississippi and was one of three accredited programs in the country. During an era of legislative conservatism, the Manufacturing Engineering Department at USU was merged into the Department of Mechanical Engineering and became an "option" within Mechanical Engineering. During these years, the Mechanical Engineering Department managed to maintain manufacturing accreditation in spite of reduced emphasis and support. Utah is becoming increasingly high-tech with some 3800 small manufacturing companies operating in

the state. In this environment, the importance of the manufacturing program at USU is gradually becoming more widely acknowledged and appreciated.

The Society of Manufacturing Engineers (SME) initiated a sweeping reformation of manufacturing education in the early 1990s resulting in a comprehensive series of publications calling for change.[1,2,3] SME announced the Manufacturing Education Plan (MEP) in August of 1996. The objective of the MEP was to motivate the academic community to help improve the competency of the manufacturing workforce.[4] The MEP focused on identifying and closing competency gaps, defined as skills and knowledge desired by industry, but often missing among newly hired graduates. Subsequently, the now famous list of 14 Competency Gaps was developed with broad-based industrial endorsement and support.[4] The list included: Communication Skills, Teamwork, Manufacturing Principles, Reliability, Project Management, Manufacturing Processes, Business Skills, Quality and Standards, Change Management, Statistics and Probability, Ergonomics (Human Factors), and Materials. The gap defining working groups also referred a category called Personal Attributes that included leadership qualities, sensitivity to others, professionalism, integrity, global awareness, and a commitment to lifelong learning. The similarities to the ABET 2000 "a through k" criteria are obvious.[5]

On the basis of a competitive proposal process, USU received one of nine SME-MEP Grants awarded in 1998.

Objectives of the MEP Grant Supported Project

The long-range objectives of the project included developing a more seamless lifelong educational model, with enhanced communication and interactive involvement among K-12, community colleges, universities, industries, and professional societies. We would place greater emphasis on team-based, project oriented, industry focused, student-empowered concepts consistent with the lean practices of world-class manufacturing.

The main thrust of the effort was to formulate a curriculum that addressed with greater fidelity the 14 competency gaps in such a way as to also meet ABET 2000 guidelines. This included a facilitation of student/ faculty co-ops and industry exchanges. A key element, in addition to curriculum reform and enhanced partnering with industry, was to develop a better method of assessment and continuous program improvement.

We also wanted to further develop our capability for distance delivery of manufacturing courses to better meet the distance education needs of the large community of engineers already in the work place.

Accomplishments

We will briefly summarize accomplishments and impacts and discuss lessons learned based on the deliverables from the SME MEP project.

Teaming Arrangements with industry

Increased industrial teaming has been perhaps the major achievement of this entire effort. Here are some examples. As a direct result of the SME grant we were able to attract a highly qualified Ph.D. level Manufacturing Engineer, with extensive industrial experience. He taught manufacturing classes and assisted with curriculum development. He brought industrial know how and hands-on expertise that the students greatly appreciated. During the first year, he attracted 26 senior engineering students to work on six industrial sponsored senior design projects in the manufacturing arena.

An electronic sign manufacturer sponsored the junior design project the first year of the grant period. The entire Junior class with more than 70 students, was involved in a manufacturing oriented team design experience with company engineers. Company engineers were coming to the design lab, answering questions, leading plant tours, grading projects and implementing student ideas.

An aluminum extrusion manufacturing company sponsored the junior design project the second year of the grant period. This project involved more than 60 junior level students in a competitive design effort. Company engineers mentored, monitored, and helped judge the design competition. The winning designs have been incorporated into plant operations.

These projects were reported in Utah Newspapers and raised the visibility of Manufacturing Engineering at Utah State.

This emphasis on manufacturing oriented teaming arrangements with industry will continue. The Director of the Utah Manufacturing Extension Partnership (MEP) will direct the junior design course this year. He is intimately acquainted with many of Utah's 3800 small manufacturing companies through working directly with these industries helping to solve their planning and operational problems. His manufacturing background and connections with the Utah manufacturing community ensures that student design projects will have industry partner involvement. Furthermore an agreement with the Department of Electrical and Computer Engineering has been established that provides for interdisciplinary teaming with MAE and ECE students. The design courses for both departments have been scheduled at the same time and will be team-taught with engineers from industry. The course will also involve marketing and manufacturing management faculty and students from the College of Business.

During the grant period, industry contributed over a million dollars in the form of cash, equipment, and internships in direct support of the manufacturing program at USU. This total does not include travel and time of engineers from industry to campus to supervise design reviews, work with students, present seminars and participate on advisory boards.

A departmental industrial advisory board with a strong manufacturing representation has been organized as a direct result of the SME emphasis on "Teaming Arrangements" with industry. The advisory board includes representatives from several major employers of USU/MAE graduates. We have attempted to include a spectrum of experience from senior management to recent graduates. The general charge to the Advisory Board is to strengthen the partnership

between the Department of Mechanical and Aerospace Engineering at Utah State University (USU/MAE) and its industrial constituency. The board is invited to advise the faculty regarding desired competencies of graduates, and observable competency gaps of intern level students and graduates. The advisory board actively promotes and facilitates opportunities for assessment and feed back from alumni now working in industry, educational linkages to the engineer in the workplace, improved and expanded facilities and equipment, student internships and work based learning, industry sponsored design projects, industry sponsored research, integrating industry expertise into the teaching/learning process, and faculty sabbaticals and consulting with industry.

Our departmental newsletters, circulating to 1500 alumni and industrial friends, further identifies the kinds of industrial partnering arrangements we continue to seek. We have not yet been able to interest any of our extremely busy faculty in sabbaticals to industry. One obstacle is the perception that this type of experience is not particularly helpful in the academic promotion-tenure process. We are making progress in changing the academic mindset regarding the value of industrial association and work but it is frustratingly slow.

Facilitate students/faculty co-ops

We have devoted a major effort to see that our students have internship experience. The manufacturing related internships have increased substantially during the grant period. We now have more than 40 companies' offering opportunities for manufacturing type internships to our students. Based on the strong industrial support we are considering requiring an internship experience for graduation in manufacturing engineering.

Curriculum reform

Over the duration of the SME Grant the manufacturing curriculum was reformed. The six new manufacturing classes detailed below were developed and taught. Manufacturing applications were integrated into some of the core Mechanical Engineering classes.

MAE 6640-Life Cycle Engineering
Fall 1998 – 7 students
Fall 1999 – 10 students

MAE 6930-Integrated Manufacturing
Fall 1999 – 8 students
Fall 2000 – 4 students

MAE 6800-Advanced Machine Design
Fall 1999 – 6 students
Fall 2000 – 46 students

MAE 5600-Manufacturing Process Planning & Statistical Quality Control
Fall 1998 - 14 students
Fall 1999 – 25 students
Fall 2000 – 11 students

MAE 5640–Design for Manufacturability
Spring 1999 – 9 students
Spring 2000 – 24 students

MAE 5680-Manufacturing Planning and Simulation
Spring 1999 – 30 students
Spring 2000 – 19 students

The *Manufacturing Education Plan: Phase I Report*[4] was utilized in our curriculum reformation.

Shown below are the expected student outcomes. These outcomes describe what every student is expected to do before graduating and reflect both SME's 14 Competency Gaps and ABET's a through k criteria.[5]

Undergraduate Program Outcomes
(Manufacturing Engineering)

1. Fundamentals: Students will identify, formulate, and solve basic engineering problems utilizing
   - **a.** linear algebra.
   - **b.** calculus-based statistics.
   - **c.** multivariable calculus.
   - **d.** differential equations.
   - **e.** calculus-based physics.
   - **f.** chemistry.
   - **g.** material science.
   - **h.** solid mechanics.
   - **i.** fluid mechanics.
   - **j.** thermal science.
   - **k.** manufacturing principles.

2. Communication: Students will develop and demonstrate the ability to communicate engineering information, including geometry, technical concepts, and results, by
   - **a.** participating in oral presentations.
   - **b.** writing proposals and reports.
   - **c.** developing engineering drawings and specifications.
   - **d.** participating in team-based engineering projects.

   These skills are developed in the senior project experience. All senior project students are required to work in teams of at least three students, make at least two formal presentations, and complete a thesis quality bound report that includes all analysis, engineering drawings, and a complete description of the project results.

3. Laboratory experiences: Students will participate in and evaluate laboratory experiences, which
   - **a.** include experimental design, data collection, manufacturing process monitoring and data analyses.
   - **b.** incorporate the use of modern laboratory and data acquisition equipment.
   - **c.** utilize statistical process analysis and interpretation of data.
   - **d.** apply manufacturing processes to the production of products.
   - **e.** may include work-based learning experiences, such as internships.

   These skills are developed in several of the undergraduate courses including instrumentation, fluids/thermal lab, and senior project.

4. Computer-based engineering: Students will demonstrate proficiency in the application of computer technology to engineering problem solving through the
   a. application of modern numerical methods and computational techniques.
   b. design and development of engineering software.
   c. integration of numerical solutions into the engineering process of design and analysis.
   d. use of current commercial engineering software including manufacturing process modeling and manufacturing data management.

5. Humanities and social sciences: Students will acquire significant exposure to the humanities and social sciences so as to
   a. provide an appreciation for the broad impact of engineering solutions on society.
   b. demonstrate an understanding of the fundamentals of the history, principles, form of government, and economic system of the United States.
   c. demonstrate a knowledge of contemporary global issues.
   d. contribute to the development of the individual as a responsible well-rounded citizen.

6. Design and synthesis: Students will participate in the design and realization process in which they will
   a. develop a set of multidisciplinary engineering requirements.
   b. synthesize material from mathematics, science, and engineering fundamentals to solve manufacturing engineering problems.
   c. design, develop, and verify software to solve manufacturing problems.
   d. bring a system from requirements definition to concept development, then specification, prototype and testing, and production or fabrication using significant engineering analysis.
   e. demonstrate the links between design, prototyping, testing, manufacturing, and other disciplines.
   f. manage a project including budgeting and detailed planning.

   These skills are taught and reinforced during the senior project. Students are required to manage a project schedule, track project costs, manage the project with weekly meetings, communicate the project to the machinists, assemble their design, and verify the performance.

7. Independent learning: Students will recognize the importance of, and demonstrate the skills required for, independent learning through
   a. independent study required in the engineering curriculum.
   b. exposure to case studies in ethics and professional responsibility.
   c. exposure to advanced topics in engineering science.
   d. exposure to advanced topics in engineering research.
   e. studying for and passing the Fundamentals of Engineering Examination.

In the following table, we have mapped the SME Listed Competency Gaps with undergraduate manufacturing program outcomes. While there are areas that continue to need strengthening, much progress as been made since the beginning of the grant period.

SME Listed Competency Gaps	*MAE Outcomes in Which This Competency is Addressed* (see Outcomes in previous section)
Communication Skills	2a, b, c, d
Teamwork	2a, b, d; 3a, e; 6a, d, f
Personal Attributes	5a, b, c, d
Manufacturing Principles	1k, 3a, b, c, d; 6c
Reliability	6a, b, d
Project Management	6c, d, e, f
Manufacturing Processes	3c, d, e; 6c, d, e
Business Skills	5a, b, c, d; 6f
Quality	3c, 6d, e, f
Change Management	6f
Statistics & Probability	1b
Ergonomics	6a, b, c, d, e, f
Materials	6b, d, e
Continuous Learning or Lifelong Learning	7a, b, c, d, e

The curriculum is available at www.usu.mae.

Integral to the curriculum reform process is assessment and corrective action. In conjunction with our constituencies that include industrial and student advisory boards, the faculty has developed a mission statement, objectives, desired outcomes and attributes for our graduates along with a methodology for improving the process. It is noteworthy that the assessment-corrective action methodology is based on manufacturing statistical quality control principles. We believe this methodology is unique and has sufficient merit to be of value to engineering educators. We plan to present a paper on this topic in Session 2566 of this ASEE 2001 Annual Meeting.

Manufacturing Design Center

The Engineering Design Center includes: offices for the Center Director and for the Engineering Internship and Placement Director, student team meeting space, reception area for industrial partners and visitors, computer and reproduction equipment for student report preparation, and a conference room for student presentations.

In adjacent or nearby rooms are project laboratories, including the Manufacturing Systems Laboratory. We are working to implement the expanded vision of the Design Center in which USU developed data compression technologies allow the electronic exchange of information and

images in real time over phone lines or the internet. The Data Compression Center is located adjacent to the Design Center to facilitate this objective.

Teaming with the College of Business

There is wide spread consensus that engineering graduates need more exposure to business skills and to have teaming experience with those in areas such as management, marketing, quality, human resources and accounting.[6,7] As part of the SME Grant effort, we determined to strengthen teaming with the College of Business. The College of Business at USU has had for the past 28 years an exemplary "Partners in Business" Program that brings to campus luminaries from the world wide manufacturing and business community to participate in annual state-of the -art seminars. Speakers have included W. Edwards Deming, Joseph Juran, Tom Peters, Malcolm Forbes and the CEOs of many of the Fortune 500 companies. We are encouraging our manufacturing students to participate in this seminar.

We are requiring all manufacturing students to take a course on Contemporary Manufacturing Management. This course, taught by Dr. Ross E. Robson, Director of the Shingo Prize for Excellence in Manufacturing and Director of the Partners in Business Programs, examines principles in manufacturing management that are driving high performance and continuous improvement in business today.
Cooperation between Manufacturing Engineering faculty and the Manufacturing faculty in the College of Business has grown over the grant period. Several productive meetings resulted in some noteworthy results. A member of our faculty joined the Shingo Prize inspection teams that visit manufacturing plants nominated to receive the prize. Marketing faculty and students will be participating in our engineering junior design project.

Business students have enrolled in our newly developed Life Cycle Engineering class. Some did very well while some did poorly. Much more successful has been the enrollment of our Engineering students in the business courses.

Summary

The SME MEP Grant truly had a major impact at Utah State University. Students felt the major impact through new classes in Manufacturing that made new topics available for the first time at USU and more closely addressed the 14 competency gaps identified by industry. Additional laboratory space was made available to manufacturing in response to initiatives made possible by the grant. Grant funds supported graduate students working to build the manufacturing program and help meet grant objectives. This was leveraged into additional student support through faculty proposals.

Grant funds made possible an arrangement with the local Applied Technology Center (ATC). Our engineering students prepared and submitted shop drawings to the ATC . Students at the ATC then machined components and systems from the drawings. Both the engineering and the

technician students benefited from the experience. The Engineering students were forced to prepare error free drawings rather than designing in the shop as had been done previously. They also honed teaming and communication skills in the process.

Many of the industrial customers that employ our graduates have agreed to a partnership in the educational process. We are certain that as a result of grant sponsored activities our relationship with industry was greatly strengthened. Our students and faculty benefited and our industrial partners are enthusiastic about the results.

Partnering with the College of Business brings valuable exposure to our students while reducing the load of an already over burdened engineering faculty.

The SME grant and association with SME headquarters has served to stimulate greater activity in making the K-12 connection than ever before. A paper detailing this activity is scheduled for presentation in Session 2530 at this ASEE 2001 Annual Meeting. The paper suggests that engineering education would do well to follow the manufacturing model for improving quality by bringing all stakeholders onto the product realization team including both customers and suppliers.

We believe the SME played an important role in bringing about a more favorable climate for manufacturing engineering education at the university and across the state. Based on our initiatives, Governor Leavitt requested a meeting with National SME leadership early in the grant period. That meeting influenced his thinking. The Governor's initiative to double the number of graduates in engineering from Utah schools will surely emphasize manufacturing.

The impact of the grant on the attitude of our faculty toward manufacturing was also important. The department head had the opportunity to visit SME headquarters and get acquainted with SME staff and leadership. Manufacturing topics acquired more stature and respect in faculty discussions. These are all subtle but very real factors.

We are very appreciative to the SME for the MEP grant and the impetus provided to our program. We look forward to a continued partnership with SME as we continue to build and improve the quality of our Manufacturing Engineering program.

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J. CLAIR BATTY is Professor and Department Head of Mechanical and Aerospace Engineering at Utah State University in Logan, Utah. He teaches both graduate and undergraduate courses in Thermodynamics and Heat transfer. He and his graduate students are currently conducting research in the thermal management of space systems at Utah State University's Space Dynamics Laboratory. He received the Sc.D. degree in Mechanical Engineering from the Massachusetts Institute of Technology in 1969.

JOHN K. GERSHENSON is an Associate Professor in the MechanicalEngineering – Engineering Mechanics Department at Michigan Technological University. Previously he worked at Utah State University and the University of Alabama. His research interests center on life-cycle engineering and decision making. Specifically, he has looked at the interrelationships among design, manufacturing, and the environment.

CARL G. WOOD is an Associate Professor in the Department of Mechanical and Aerospace Engineering at Utah State University in Logan, Utah. He has extensive industrial experience and is currently directing the Manufacturing Engineering Program at USU. He received the Ph.D. Degree from Brigham Young University in 1986.