

Integrating Team Development into a Manufacturing Technology Course

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Abstract

As manufacturing companies have made known their need for engineers who can communicate well, work on diverse teams, and engage in concurrent engineering, the Mechanical Engineering Technology Department at the University of Maine has responded to those needs by revising and updating its manufacturing courses. “Manufacturing Technology” (MET 270) is designed for second year students, Fall semester. MET 270 was previously taught as a lecture course describing a wide range of manufacturing processes. Student teams presented studies of local companies at the end of the course. MET 270 now focuses on the concurrent engineering of products. The technical content is presented using a variety of media including lecture, cooperative learning activities, web-based training, films, and student tours. Communication and team skills are practiced during in-class exercises. For three families of processes, small student teams design simple products, develop CADD drawings and engineering analyses to support the designs, and describe in detail how the products will be fabricated and what the impacts of the fabrication processes are on the designs. The teams submit written reports and make oral presentations to the class describing their products. The class syllabus is designed to support the new ABET criteria for accrediting Engineering Technology programs.

Introduction

At the University of Maine, students in the Mechanical Engineering Technology (MET) program complete a core of courses focusing on manufacturing. Five of these courses are laboratory based. The remaining course, MET 270 Manufacturing Technology, is a lecture class which introduces manufacturing processes for metal, plastic, paper, and assembled products. This second-year Fall semester course has undergone major revision over the past two years. Previously students were introduced to many manufacturing processes but at a superficial level. MET 270 now focuses on concurrent engineering of manufactured products. Students investigate fewer processes but in greater depth. Those processes that are treated in the laboratory courses were removed from the MET 270 syllabus and processes relevant to Maine industries were added.

The new program evaluation criteria established by the Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET) and the graduate competency gaps cited in the Society of Manufacturing Engineers (SME) Manufacturing Education Plan Phase I Report were addressed in the new course design.^{1,2} Students must practice and demonstrate teamwork, communication, and lifelong learning skills. Team-based projects have replaced individual question-and-answer homework assignments. Teams are

required to design wrenches and to describe the relevant design parameters for the manufacturing method selected. Projects are presented orally and in written reports that incorporate computer-aided design and drafting (CADD) drawings and design calculations. The drawing and calculations relate directly to prerequisite and corequisite coursework. The reports reference design criteria suitable for use at a professional level.

Student work quality, class participation, and class morale have improved with the changes. I arrived as a new faculty and taught to the established syllabus in Fall 1997. Coming from an engineering position at a shipbuilding firm, I was experienced with teamwork and concurrent engineering methods. However, that first year I did not arrive with the pack full of anecdotes and personal experiences that students expected relating to the wide range of processes covered in the lecture. While developing credibility can be challenging in every position, I found it to be particularly difficult as a new female faculty in an eight o'clock morning class of 44 men and one woman, describing manufacturing processes without the "hands-on" experience so respected by technology students.

I chose to modify the course content to address the TAC and industrial requirements and to add depth and interest to the topics. At the same time I shamelessly shifted the content to better reflect my own manufacturing experience.

Baseline Year: Fall 1997 Syllabus and Evaluation

The Fall 1997 syllabus for MET 270 addressed a wide range of distinct reading and lecture topics including measurement, inspection, nondestructive testing, quality control, expendable-mold and multiple-use-mold casting methods, powder metallurgy, hot and cold working processes, plastics, ceramics and composites, metal cutting, cutting tools, turning, boring, drilling, milling, broaching, sawing, abrasive machining, machining centers, thread and gear manufacture, nontraditional machining processes, welding processes, brazing, soldering, and adhesive bonding. Students were expected to learn "definitions" of the processes. The format was fifty-minute lecture, question-and-answer homework assignments, and several tests.

The five laboratory classes in the manufacturing sequence introduce students to drawing and machining skills. Students develop hand and CADD drawing techniques in Technical Drawing and Machine Drawing. In Machine Tool Laboratory I students machine a project, and in Machine Tool Laboratory II students machine a project that they have designed and drawn in Machine Drawing. Students create computer numerical control (CNC) codes from drawings and learn the basics of welding in Introduction to Computer Aided Machining (CAM) and Welding. A large portion of the baseline year MET 270 syllabus focused on the machining, CNC control, and welding topics of the laboratory classes.

In the baseline year students also performed company studies. Student groups visited a manufacturing company and group members reported orally to the class about the company organization, processes, marketing, etc. While they responded positively to studying the companies, they did not all respond positively to working in groups. In fact some of the more extreme resistance problems led me to propose that a curriculum development change be funded through the Women in the Curriculum (WIC) program at the University. The purpose of the

proposed change was to improve students' skills in dealing with diversity through teamwork development activities.

The syllabus of MET 270 was discussed at our departmental Industrial Advisory Committee meeting in the Spring of 1998. Committee members were supportive of the idea of reducing the number of topics and dealing with a few of them in more depth.

Year 1 Improvements: Fall 1998 Syllabus and Evaluation

In the Fall 1998 syllabus the majority of the machining topics were removed, as were welding and CNC, since these were the topics of other required courses. This resulted in time available for development of three new topics: the unit funded through WIC titled "Success Working in Diverse Teams," papermaking, and robotics/assembly.³ The two latter choices were incorporated for two reasons: 1. our MET graduates are likely to be employed in these industries; 2. the University of Maine has a pilot paper plant and a recently donated assembly machine. The syllabus was divided into four units: "Success Working in Diverse Teams," papermaking, metal part fabrication, and non-metal part fabrication and assembly.

In addition to syllabus changes classroom time was restructured. Fifty minute lecture with board notes was replaced with short lecture and active and cooperative learning activities.^{4,5} Some suitable films and applied reference materials from trade journals were utilized in class and in assignments. Question-and-answer homework assignments were replaced with open-ended report writing. Teams of students used their individual reports to present written and oral team reports. Students toured the pilot paper plant during the papermaking unit. They made detailed observations of the operation of the assembly machine, which assembles three-piece anchor and clip units to secure electrical wiring on assembly machine extruded aluminum frames. Students performed company studies that were similar to those of Fall 1997 but somewhat less extensive.

The course materials used for the teamwork topics were taken from library resources, web-based journal articles describing the implementation of work teams in manufacturing plants, and materials from the Midwest Center for Advanced technology Education (MCATE) Team Development Workshop.⁶⁻⁹ Tuckman's model of team development was presented and students used in-class team development exercises and self-evaluation materials. They wrote reports about how teamwork is applied in manufacturing environments. Materials for diversity topics included films, and articles and reports about the status of women in engineering careers.¹⁰⁻¹⁵ Students wrote reports about how people from diverse backgrounds are included in teams. They worked in teams to present oral reports describing a 4-point plan that a company could use to establish work teams and to attract a diverse workforce.

After the unit "Success Working in Diverse Teams" of eight class sessions students were asked to respond anonymously to a variety of questions about the unit goals, materials, and classroom climate. Some aspects of the unit worked well while others did not. Student feedback toward this first unit was generally positive. The class consisted of twenty Caucasian men from the northeastern U.S. One student insisted on this form and to the administration of the School of Engineering Technology that the "diversity part" was not part of the published course description and that he objected to participating in it. The eight o'clock class time remained unchanged and

unpopular. However, students overwhelmingly stated that they preferred the active learning environment to lecture because it was more stimulating. Based on student behaviors during the remainder of the course I was not satisfied that the unit resulted in significantly improved ability to establish team norms which capitalized on diverse experiences, expectations, and personal realities. Students made and accepted comments reflecting stereotyping at various points throughout the term.

Students displayed increased depth of understanding of the “technical” syllabus topics through their written reports when compared to homework questions of the previous term requesting “definitions.” After visiting the pilot paper plant students wrote and presented team reports about papermaking. Individual students performed similar assignments about using casting, forging, and non-traditional machining methods to fabricate metal parts. In each assignment they were required to describe how a specific process from a family of processes could be used to manufacture a part. Teams made summary oral presentations based on the individual assignments. Teams also presented company studies of local companies manufacturing non-metal products. Students developed statistical process control charts and took several short quizzes.

The textbook, which remained unchanged from the baseline syllabus, did not offer a format that supported the assigned topics well.¹⁶ The book did not offer enough examples relating developing part design requirements for a given manufacturing method. Selecting appropriate fabrication methods and improvements in fabrication methods are important skills for MET graduates in manufacturing environments. Required with those skills is the ability to remain current and to relate how advances could be applied to part design and manufacture. As a result a goal was to increase the emphasis on lifelong learning in the Fall 1999 term.

I found that I enjoyed teaching MET 270 much more in the Fall 1998 term than in the Fall 1997 term. The primary reason was the incorporation of various active learning approaches, tours and films in class. I do not enjoy being the “sage on the stage.”⁵ The new approach resulted in routine student class participation and a much better chance for me to get to know my students, their strengths, and their weaknesses. I have enjoyed much improved class attitude and interpersonal relationships with individual students since I have moved to a more interactive approach.

Year 2 Improvements: Fall 1999 Syllabus and Evaluation

The syllabus improvements in MET270 of Fall 1998 were accomplished based on my subjective evaluation of the course and its relationship to manufacturing environments. As I was revising the syllabus during the summer of 1998 I was aware of but not using the then proposed TAC program evaluation criteria which are now in effect.¹ I obtained the SME Manufacturing Education Plan Phase I Report during the Fall 1998 term.² By the summer of 1999 I realized that my perception of required course revisions was supported by applicable published criteria. These publications were used as the basis for improvements in the Fall 1999 term.

A different text which emphasizes concurrent engineering was selected.¹⁷ The syllabus was revised to reflect the progression of the new text. The term was divided into several units: 1.

Casting (including introduction to teamwork and concurrent engineering); 2. Forming; 3. Powder Metallurgy and Plastics; 4. Automation and Assembly; 5. Company Studies. The science and engineering librarian at the Fogler Library at the University of Maine searched library and web-based materials for each of the first three units. She provided a very helpful materials resource list that included a limited number of highly appropriate materials suitable for active professionals and students.¹⁸⁻²¹ Written, film, web-base, and CD-ROM sources were identified and obtained from organizations of manufacturers promoting their processes including the American Institute of Steel Construction, Inc., the North American Die Casting Association, the Steel Foundry Society of America, the Forging Industry Association, the Metal Powder Industries Federation, the European Powder Metallurgy Association, and The Association of Pulp and Paper Industries. Several General Electric training films regarding casting, forming, and powder metallurgy processes became available for use in the course.²²⁻²⁴ Society of Manufacturing Engineer films were also available.²⁵

At the time of this writing students have completed twelve weeks of the fourteen-week Fall 1999 term. The discrete unit "Success Working in Diverse Teams" was not included in the Fall 1999 syllabus. Instead, teamwork development was integrated throughout the syllabus. Nearly all assigned homework has been in the form of team projects. Students have written team contracts, developed and used "Action Item" lists to support their team projects, and observed other teams' meetings and noted their interactions.⁷ Discussion of diversity was limited to those types of diversity evident in their teams. The class consists of twenty-eight men and two women, all Caucasian from the northeastern U.S. A goal has been to focus in Fall 1999 on improving the teamwork development materials. Introducing diversity topics relevant to teamwork is planned in later years.

For each unit, films with film notes have been used to introduce the manufacturing processes. Films have helped students to visualize the manufacturing environment and specific processes. Lecture has been used to support, in particular, product design requirements and limitations for the different processes. All class material has been related directly to successful completion of their projects. The textbook reading material has closely supported the projects. This approach has assisted students in focusing on applying the course concepts to their projects outside of class.²⁶

Students have completed team projects requiring them to design a wrench, provide CADD drawings and structural analysis of the wrench, and describe a manufacturing method to manufacture the wrench. The same functional requirements were assigned for wrenches manufactured using casting, forming, and powder metallurgy processes. The casting and forming projects were quite realistic. While powder metallurgy production of a wrench is currently far-fetched, use of the same product has allowed students to study necessary design changes to accommodate different processes. For example, the competition for business between die casting and powder metallurgy manufacturers was made clear through this approach. Students have been provided lists of the library and web-based reference materials recommended to support their projects. A team member has presented the project results to the class and the teams have submitted written project reports. The quality of the materials submitted has far exceeded that of both previous years in depth and integration of the product and the process.

MET 270 Manufacturing Technology
 Fall 1999
 Self-assessment form

Student identification (last 4 digits of your current phone number)_____

1. Please fill in the last four digits of your current phone number. This self-assessment will be repeated at the end of the course; the identification is to correlate your later self rating with your current self rating.
2. Please rate your current knowledge in each area from 1 (very limited) to 5 (substantial) when applied to the topic of Manufacturing.

TAC Assessment Categories		Self Rating
a	demonstrate an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines	
b	apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology	
c	conduct, analyze and interpret experiments and apply experimental results to improve processes	
d	apply creativity in the design of systems, components or processes appropriate to program objectives	
e	function effectively on teams	
f	identify, analyze and solve technical problems	
g	communicate effectively	
h	recognize the need for and possess the ability to pursue lifelong learning	
i	understand professional, ethical and social responsibilities	
j	recognize contemporary professional, societal and global issues and are aware of and respect diversity	
k	have a commitment to quality, timeliness and continuous improvement	

Accreditation Board for Engineering and Technology (ABET) web site: <http://www.abet.org>. The web page detailing the proposed Technology Accreditation Commission (TAC) criteria is http://www.abet.org/tac/New_TAC_Criteria.htm.

Figure 1
 Student Self-assessment Form Used at Start and End of Course

Evaluation and Continuous Improvement

Evaluation of individual student skills is being accomplished through reading quizzes and two examinations. Their teamwork skills are being evaluated using their responsiveness to their assigned action items, adherence to their team contract, and my observations of in-class team preparation time. Developing self-assessment criteria and external assessment criteria for teamwork skills is a future goal.

Evaluating the effects of the syllabus improvements based on student perceptions will be carried out in three ways. At the beginning of the term the SME Manufacturing Education Plan and TAC (ABET) criteria were discussed with the class.^{1,2} Students then anonymously self-assessed their skill levels relevant to each of the TAC criteria as shown in Figure 1. At the end of the course they will again anonymously self-assess their skill levels. The individual and average changes in self-assessment will be used to help evaluate the effectiveness of the current syllabus and make further improvements. This approach has been used at the University of Maryland.²⁷ Students also provided anonymous feedback at the midterm point. Some suggestions were used to make minor changes in classroom procedures, but otherwise that feedback did not indicate any reasons from the student perspective to change the current approach. At the end of the term students will again evaluate the course with the opportunity to use narrative comments. These forms of student feedback will be used to introduce further improvements.

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