Integrating Service-Learning in a Sophomore-level Materials, Manufacturing & Design Lab*

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Abstract

Service-learning was successfully integrated into a sophomore-level course to teach materials, manufacturing and engineering design to mechanical engineering students. The course met a program need for a sophomore course with substantial design content and the service-learning design projects carried out by the students met two needs of the K-16 community. Based on the performance on graded materials, a great majority of the students were able to achieve the performance criteria established by the instructor in engineering design process, strain hardening and annealing, statistics, and communication skills.

Introduction

The Mechanical Engineering Department, University of South Alabama, adopted design-across-curriculum as a strategy to meet the accreditation criteria of Engineering Criteria 2000. This necessitated the need for lower-division (100- and 200-level) courses with a substantial design component in addition to senior capstone design. Furthermore, the department adopted project-based learning to promote active learning. Consequently, realistic and inexpensive hands-on projects are needed to support this program goal.

The College of Engineering and the Mechanical Engineering Department have been partners with the Mobile County Public School System's SECME (Southeastern Consortium for Minorities in Engineering) program for many years. SECME sponsors an annual academic competition to stimulate interest in mathematics, science, engineering and technology. In past years, the top performing students in each of competition categories received a certificate and, when funds were available, trophies that SECME bought from a trophy shop. These trophies bore no connection to academic achievements or SECME. In Fall 1999, the SECME program coordinator and the author of this paper brainstormed ideas to address the need for trophies to award students for their academic performance in the annual SECME competition.

Also in Fall, 1999, the College of Engineering began planning to restart an annual Open House in conjunction with the National Engineers Week that targets middle- and high-school students. This event necessitated the need for hands-on activities to engage the K-12 student visitors.

These needs have been met by a sophomore-level course on materials, manufacturing and design that incorporates service-learning to provide the context for teaching and learning.

What is Service Learning?

Service-learning is a form of experiential learning in which community service provides the context for learning[1]. Service-learning has been used by engineering educators to provide the context for students to learn and practice engineering design. Service-learning design projects differ from traditional engineering design projects in the following ways:

- Service-learning projects are sponsored by community organizations while traditional design projects are sponsored by industries, professional societies, or by faculty.
- Students interact with persons outside of their socioeconomic group with little knowledge of engineering in service-learning projects. In traditional design projects, students interact with engineers, engineering faculty and students.
- Engineering and non-engineering issues are addressed in a service-learning design project.

In a service-learning design project, students will

- Work with team member(s) outside of the engineering discipline
- Be required to communicate effectively with a diverse audience
- Experience the positive impact of engineering and technology on community

Thus, service-learning design projects compliment traditional design projects in the training of engineering undergraduates regarding teamwork, oral and written communications, and design.

In past ASEE proceedings, J. Duffy of University of Massachusetts-Lowell described how to integrate the service-learning pedagogy into seven mechanical engineering courses ranging from junior to graduate levels, and in which the community-service project constitute the main focus to a small percentage of the total course work[2]. E. Tsang[3] and S. Lord[2] described how to integrate service-learning into "introduction to engineering" courses for mechanical engineering and electrical engineering students, respectively. In Purdue University's EPICS, both short-term and long-term community-service projects are carried out by a vertically integrated team consisting of first-year to senior students[4]. More examples of service-learning in engineering and the impacts on student learning can be found in *Projects that Matter: Concepts and Models for Service-Learning in Engineering*[5]. In all cases, service-learning has been found to have a positive impact on students' communication and teamwork skills, their awareness of the customer in engineering projects, and the sense of accomplishment through completion of the service-learning projects that benefited the communities.

Course Design

Course development is guided by the ideas outlined by Stice on teaching problem-solving skills[6]. According to Stice, "Learning theorists tell us that the best way...is to give students the opportunity to analyze, synthesize, or evaluate on their own. Then they must be given rapid, accurate feedback on their performance. Finally, they need lots of practice to develop their skills." Course activities are constructed with the goal of creating a discovery-oriented learning environment so students can discover for themselves the engineering principles and relationships through guided, hands-on activities. Therefore, the laboratory period begins with a 15- to 20-minute presentation on the relevance of each week's hands-on activities and to give students feedback on their work for the session, and to set in context the session's work in relation to the larger theme of the design project. The laboratory period concludes with a group discussion on the results of the laboratory investigation and the relevancy to the overall design project.

Content for the materials science and engineering portion of the course is guided by a 1989 report commissioned by the National Research Council (NRC) on undergraduate education in materials science and engineering[7], which recommends that "regardless their institutional location and organization, undergraduate courses and programs in materials science and engineering be centered on the four basic elements of materials science and engineering," which are synthesis and processing, structure, properties, and performance, and the relationships among them. For education of non-materials science and engineering students, the report recommends the joint teaching of subjects by faculty with materials and non-materials science expertise, and a sequence of two courses with one focusing, for Mechanical Engineering undergraduates, on the elastic and plastic properties of materials.

Mechanical forming is chosen as the theme because it addresses the goals outlined by the NRC, and because it provides a platform to integrate concurrent engineering design and manufacturing processes. Students will discover, through hands-on investigations, the effects of mechanical forming on the mechanical properties and microstructure of a metal. They will also discover, again through hands-on investigations, the effect of annealing on the mechanical properties and microstructure of a metal. As a result of these activities, students will be able to synthesize the relationship between processing (mechanical as well as thermal), properties and structure, and apply the knowledge in the design project. Students will apply statistical concepts such as mean and standard deviation for product description, tolerance, reliability, and quality control.

The service-learning pedagogy was adopted to meet the needs of the College and the SECME partner as identified above. This is accomplished through two design projects for the 1 credit hour laboratory course, ME 211, "Materials, Manufacturing and Design." The two service-learning design projects are:

Design Project for Fall Semester: "Design a process, including a manual, that will assist an engineering student volunteer to guide K-12 student visitors to mint a 'College of Engineering Open House' Commemorative Coin"

Design Project for Spring Semester: "Design and manufacture 31 Gold Medals, 31 Silver Medals, and 31 Bronze Medals for the annual SECME competition."

In completing either of the service-learning design projects of ME 211, students will have applied the principles of strain hardening and annealing and the effects on the mechanical properties of metals in the design of an actual manufacturing process to produce medallions that meet the community needs. Weekly laboratory exercises are designed to provide students with the knowledge and skills to complete the service-learning design project, and the opportunities to apply the knowledge and to practice those skills. Students are formed randomly into teams of 3 to 4 students. Although the students performed the laboratory activities as a team, they were often required to submit individual laboratory reports.

[Service-learning also provided the context for a 100-level course that meet the needs of the ME Department and the SECME partners. In this course, engineering students worked in teams to design instructional “hardware” and “software” that meet the needs and specifications of SECME middle-school mathematics and science teachers[8].]

Learning Objective, Performance Outcome, Assessment Method & Performance Criteria

There are four learning objectives for ME 211:

Objective #1: Students successfully demonstrate the elements of engineering design process.
Performance Outcome: Students successfully demonstrates the elements of engineering design process through the completion of the service-learning design project.
Assessment Method: Design Project Written Report, Design Project Oral Presentation, and Student Survey.
Performance Criteria: the instructor evaluated the Design Project Written Report and another ME faculty evaluated the Design Project Oral Presentation. They look for the following characteristics in the service-learning design projects:

- literature and market research
- more than 3 initial alternative ideas
- realistic design constraints and criteria with which to evaluate the ideas
- analyses backed by engineering calculations
- design iteration
- use of a decision-making matrix to evaluate and select design ideas
- design implementation and final product; and
- recommendations for continuous improvement.

The evaluators assign a numerical score based on a holistic evaluation of the student performance in oral presentation and written report using the above categories.

Objective #2: Students successfully apply the principles of strain hardening and annealing to design production procedures.
Performance Outcome: Students successfully use the data they generated on strain hardening and annealing to calculate the relevant forces in the manufacturing process and to design the production procedures.
Assessment Method: Laboratory Report and Student Survey.
Performance Criteria: the instructor evaluates how well the students use the data they generated in the laboratory assignments or obtained from handbooks to calculate the relevant forces in blanking and stamping the medallions and to design the production steps.

Objective #3: Students successfully apply sample mean, sample standard deviation, and normal distribution in product description
Performance Outcome: Students successfully apply sample mean, sample standard deviation, and normal distribution in describing the length dimension and hardness of a product.
Assessment Method: Laboratory Reports and Student Survey.

Performance Criteria: the ability of students to apply sample mean, sample standard deviation, uncertainty and confidence level in reporting the dimensions and hardness of a product in lab reports is evaluated by the instructor

Objective #4: Students practices communication skills (written, graphic, oral).
Performance Outcome: Students demonstrate competency in written, oral, and CAD communication skills.
Assessment Method: Laboratory Reports, Design Project Oral Presentation and Written Report, Student Survey
Performance Criteria: student performance in oral presentation and written report was evaluated on the following categories:

- organization of the presentation or the written report
- clarity of the oral presentation or proper mechanics of writing in the written report
- use of visual aids.

The engineering drawings contained in the laboratory reports on medallion visual design and on blanking and stamping dies are evaluated to determine a student's competency in CAD communication skills.

Students appraise how well the course objectives have been met and on the contribution of the course to their development in the relevant ABET EC 2000 Criterion 3 (a-k) performance areas, using two surveys given in Table 1.

Course Implementation

A brief summary of the weekly laboratory activities follows:

Week 1: Students use a micrometer and apply statistics (mean, standard deviation, uncertainty, and confidence level) to describe the physical dimensions of a product.

Week 2: Students calculate the blanking force and stamping force to produce the medallion, and they choose the project's material(s) based on the mechanical properties of the material(s) and the rating of the hydraulic press available for the project to produce the medallions.

Week 3: Students individually generate ideas for the visual design of the medallion. Then as a team, the design constraints and criteria to evaluate the visual design ideas are generated. Students create a decision-making matrix to evaluate and select the team's initial visual design of the medallion.

Weeks 4-6: As a team, students create CAD drawings of the visual design and cut prototypes of the visual design using a Roland Model CAMM on a wax block. Each team will perform design iteration and prepare for a presentation on the team's visual design on Week 6. Following the presentations, the class selects one visual design and sends the computer codes to the Bevil Advanced Manufacturing Center, where a stamping die plate is produced. Figure 1 is the stamping die plate for the College of Engineering Open House medallion.

Weeks 7-10: As a team, students conduct experiments to determine the effects of strain hardening & annealing on the hardness of the metals selected for the project. The results of the experiments are represented by the graphs of Figure 2, which were generated for 260 Brass O60. From the results in Figure 2, students re-determine the blanking and stamping forces, taking into account strain hardening during the manufacturing processes.

Week 11: As a team, students design the blanking die and the stamping die from the stamping die plate, which must fit within the working space of the hydraulic press to produce the medallions. They produce orthographic drawings of the dies and assemblies. The college machinist selects one design from the student's CAD drawings and produces the blanking and stamping dies, which are shown in Figure 3.

Weeks 12-13: Students produce prototypes of the medallions to identify the optimum stamping force, and they compare it to the calculated value determined in Week 10. The medallions produced by the students for the SECME competition are shown in Figure 4.

Week 14: As a team, students design the production processes and procedure, and identify the safety issues and how to address them.

Week 15: Students prepare for the design project presentation, which includes submitting a written report and making an oral presentation during final exam week.

Week 16: Final Exam: Students make Design Project Oral Presentation and submit Written Report.

Results of Student Evaluation

For Objective #1, the results of faculty evaluation are given by Figure 5, which shows the distribution of scores (normalized to 100) assigned by the instructor and by another ME faculty for four semesters. Overall, a great majority of the students were able to meet the performance criteria established by the instructors in successfully demonstrating the elements of the engineering design process in their service-learning design projects. Of the 88 students enrolled from Spring 1999 to Fall 2000, 82 students received a score >80 as evaluated by the instructor and 80 students received a score >80 as evaluated by another ME faculty. There is reasonably good correlation between the grades assigned by two different ME faculty.

For Objective #2, the laboratory report grades assigned by the instructor on students applying the principles of strain hardening and annealing are shown in Figure 6. Overall, a great majority of the students were able to meet the performance criteria established by the instructors in applying the principles of strain hardening and annealing in calculating the relevant forces in the manufacturing process and in designing the production procedures.

For Objective #3, the grades assigned by the instructor on students applying statistics based on laboratory reports are shown in Figure 7. Overall, a great majority of the students were able to meet the performance criteria established by the instructors in applying statistics in product description.

For Objective #4, the grades assigned for written communication, oral communication, and CAD communication, are shown in the Figure 8.

The results of student survey regarding how well the course learning objectives have been met and the contribution of the course to their development of relevant ABET EC2000 Criteria (a-k) performance areas are summarized in Figure 9. Based on the results of the survey, the students rated the course high in meeting the learning objectives and in contributing to their development in the relevant ABET EC 2000 Criterion 3 attributes (ability to apply knowledge of mathematics, science, and engineering; ability to design and conduct experiments as well as to analyze and interpret data; ability to design a system, component, or process to meet desired needs; ability to identify, formulate, and solve engineering problems; ability to communicate effectively; and ability to use the techniques, skills, and modern engineering tools necessary for engineering practice).

Discussions of Results

Faculty evaluation of student performance can be correlated to student self-appraisal to determine the effectiveness of the course materials. This correlation can be explained by Figure 10. In Quadrant I, student performance rated average or low by faculty (a score less than 80%) is correlated with a low evaluation by the students. This indicates that the course has not met its objectives and is not very accessible to the students. In Quadrant II, a low student performance as evaluated by faculty is accompanied by a high rating by students. While the students think they have met the performance criteria, they have not, and the course objectives were not met. In Quadrant III, an above average student performance rating by faculty is accompanied by a low student rating to indicate that the course did not contribute to student learning, most likely because the students already know the materials. In Quadrant IV, an above average rating of student performance by faculty is accompanied by a high rating by the students to indicate that the course objectives have been met and that the course contributes to student learning.

Based on the evaluation of student performance by the faculty and based on student survey, a large majority of students fall in Quadrant IV. The correlation of faculty and student evaluations indicates the course objectives of ME 211 have been met and the course contributes to student learning.

Summary & Lessons Learned

Students have quite a lot of difficulty polishing the specimens for microstructure examination. This is probably because the materials selected for the design project are relatively soft (110 Copper, 3003 Aluminum, and 360 Brass), and also because the students lacked patience to manually polish the specimens (the instructor informed the students that an unofficial course objective is to help them develop patience). After two semesters, activities on investigating the effects of strain hardening and annealing on microstructure were eliminated to provide more time for students to study the effects of strain hardening and annealing on hardness.

While the senior capstone design course may be a natural place to incorporate service-learning, this project as well as others identified in the bibliography section demonstrate that the service-learning pedagogy can be integrated into any engineering curriculum to meet both instruction needs and community needs.

* The work presented in this paper was performed by the author while he was an associate professor of mechanical engineering at University of South Alabama.

Figure 1. Die plate for stamping College of Engineering Open House Commemorative Coin

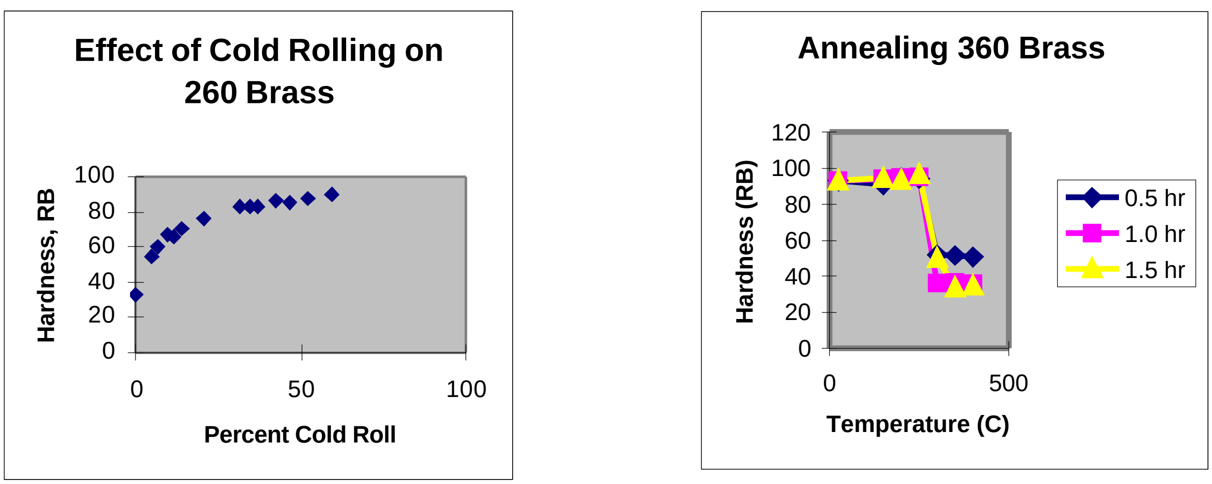

Figure 2. Strain Hardening and Annealing results for 260 Brass O60

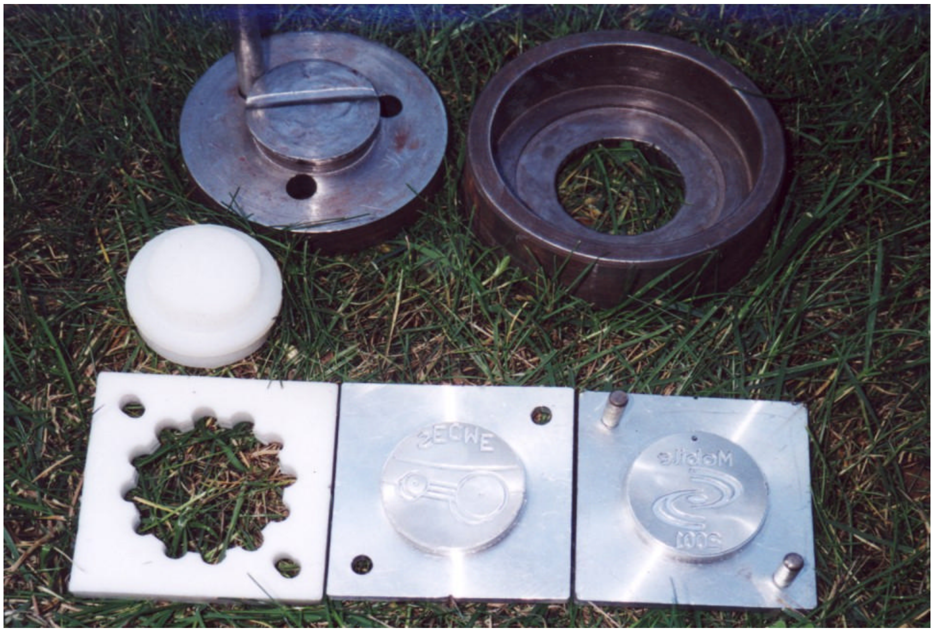

Figure 3. Blanking and stamping die and assembly to produce SECME medallions

Figure 4. Gold, Silver, and Bronze medals for SECME competition

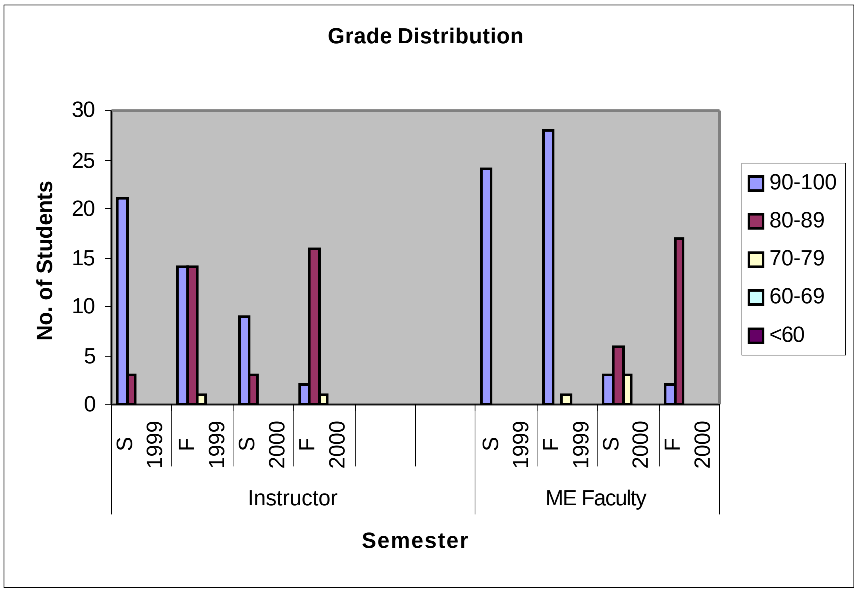

Figure 5. Grade distribution assigned by instructor (written report) and another ME faculty (oral presentation)

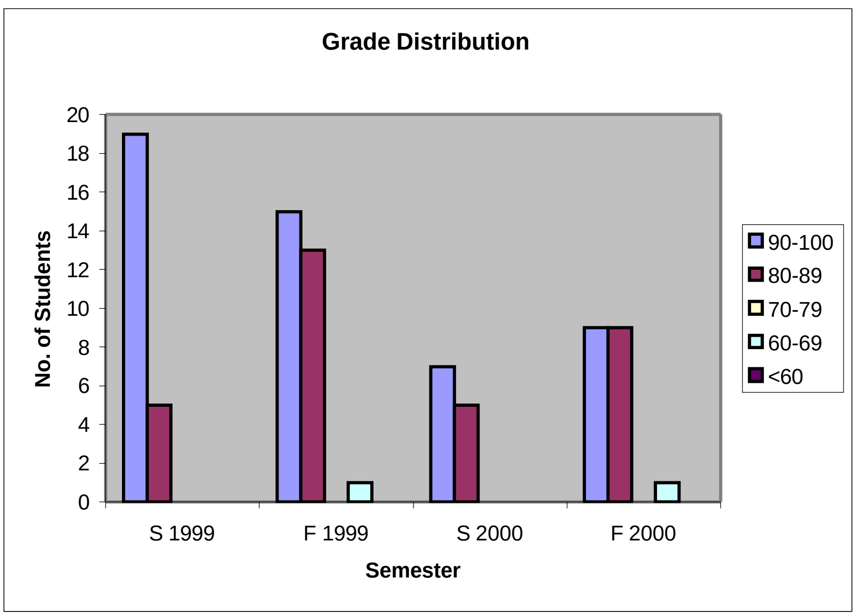

Figure 6. Laboratory report Grades on strain hardening and annealing assigned by instructor

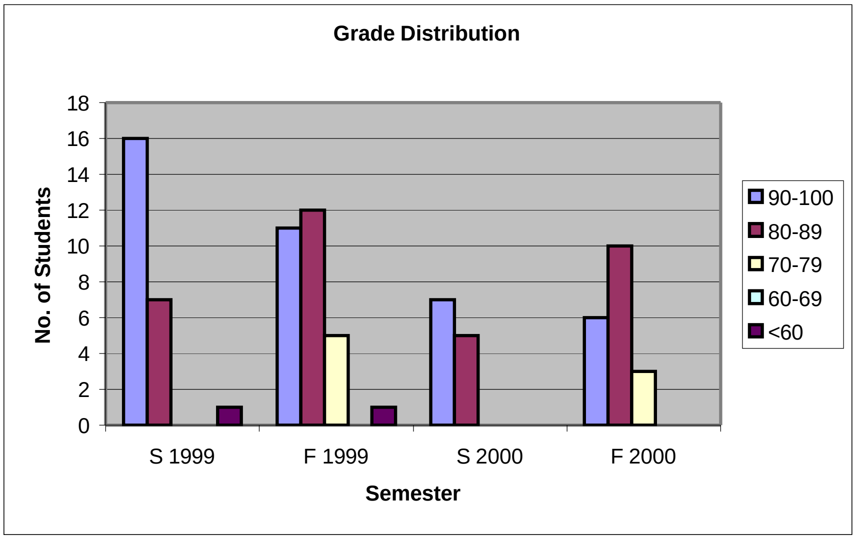

Figure 7. Laboratory report grades on applying statistics to describe a produce assigned by instructor

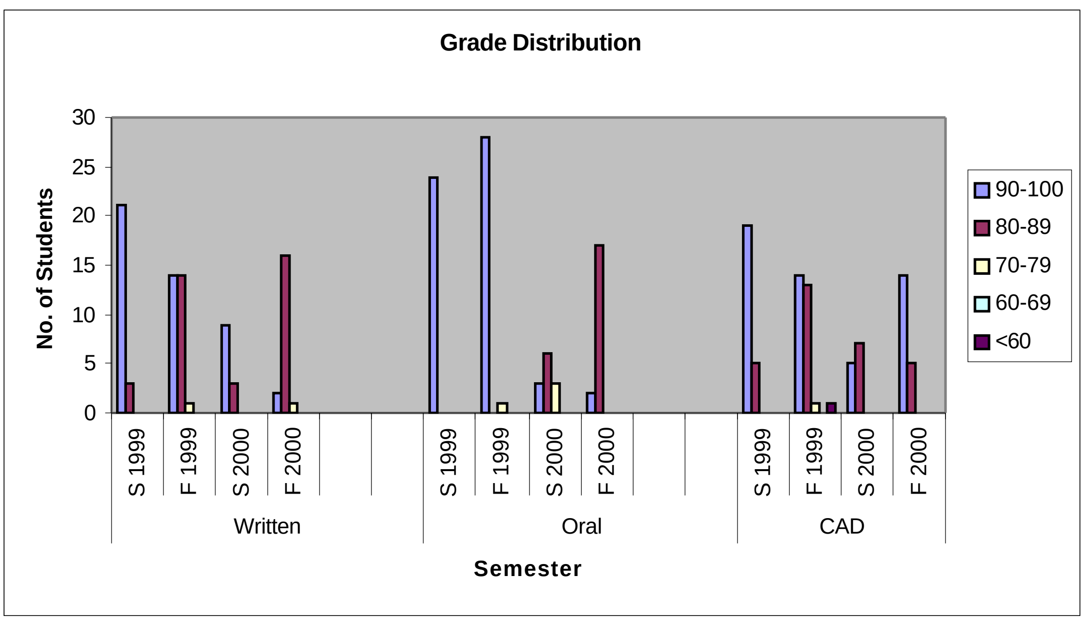

Figure 8. Grade distribution for written communication, oral communication, and CAD communication

Semester	S 1999	F 1999	S 2000	F 2000
No of Students Reporting	24	28	9	16
(the following scores are based on 0-4)				
Course Objective #1	3.84	3.68	3.84	3.40
Course Objective #2	3.84	3.74	3.48	3.28
Course Objective #3	3.84	3.72	3.48	3.28
Course Objective #4	3.84	3.68	3.84	3.40
(the following scores are expressed in %)				
ABET Criteria 3 a	96	89	100	100
ABET Criteria 3 b	96	96	100	100
ABET Criteria 3 c	92	96	100	100
ABET Criteria 3 e	96	86	100	88
ABET Criteria 3 g	92	93	100	75
ABET Criteria 3 k	88	93	78	88

Figure 9. Results of student survey on course objectives and their development in ABET EC 2000 Criterion 3 performance attributes

Student Evaluation	High	II - False Negative (X_2)	IV - True Positive (X_4)
	Low	I - True Negative (X_1)	III - False Positive (X_3)
		Low	High
		Faculty	Evaluation

Figure 10. Correlation between faculty evaluation and student self evaluation

Table 1. Survey to Gather Student Feedback

Course: <u>ME 211 Materials, Manufacturing & Design</u> Semester: ________

Indicate how well this course met course objectives by placing a score of 0 to 4 in the space provided.

0 = None of the objectives were met
1 = The objectives were approximately one fourth met
2 = The objectives were approximately half met
3 = The objectives were approximately three fourths met
4 = The objectives were completely met

Score	Objective
__	1. Students successfully demonstrates the elements of engineering design process
__	2. Students successfully applies the principles of cold working and annealing to design production procedures
__	3. : Students successfully applies sample mean, sample standard deviation, and normal distribution in product description
__	4, Students practices communication skills (written, graphic, oral)

This course has enhanced my:		YES	NO
A	Ability to apply knowledge of mathematics, science and engineering		
B	Ability to design and conduct experiments, as well as to analyze and interpret data		
C	Ability to design a system, component or process to meet desired needs		
E	Ability to identify, formulate and solve engineering problem		
G	Ability to communicate effectively		
K	Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice		

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Biography

Edmund Tsang received his B.S. in mechanical engineering from University of Nebraska and his Ph.D. in metallurgy from Iowa State University. He is presently the associate dean for undergraduate programs and assessment at Western Michigan University's College of Engineering and Applied Sciences. Dr. Tsang's interests include enhancement of the lower division engineering curriculum and integration of service-learning into engineering.