Integrating Service Learning into Introduction to Mechanical Engineering

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ABSTRACT

Service learning is a method under which students learn and develop through active participation in thoughtfully organized activities that are conducted in and meet the needs of a community. Service learning is integrated into and enhances the academic curriculum of a freshman Introduction to Mechanical Engineering course by providing the context of teaching and learning design. The emphasis is on experiential learning, and service is a by-product of the learning experience. At the University of South Alabama, Service Learning is implemented by a partnership between the SECME (Southeastern Consortium for Minorities in Engineering) program of the Mobile County Public School System in Mobile, Alabama and the Mechanical Engineering Department. First-year mechanical engineering students are formed into design teams, and each team is paired with two middle-school teachers serving as customers for the design projects. The design teams design, produce and test an instructional module and manipulate(s) that promote a thematic approach to mathematics and science instruction and hands-on learning in middle-school classrooms. Course content and implementation plan are described in the paper, and results of student and teacher assessment will be presented at the conference.

INTRODUCTION

The faculty of the Mechanical Engineering (ME) Department at the University of South Alabama (USA) began, in Fall 1993, an evaluation of the undergraduate program to meet the challenge of engineering education for the 21st Century. Restructuring of the mechanical engineering curriculum at USA is also prompted by the changing ABET (Accreditation Board for Engineering and Technology) requirements for design. Under the current criteria, design is defined as "an experience that must grow with the student's development," and "the design experience is developed and integrated throughout the curriculum"[1].

A new curriculum, which provides greater flexibility to upper division students to meet their diverse interests and which enhances the design experience for lower division students, was implemented in Fall, 1995 as a result of that effort. A new, four-credit hour "Introduction to Mechanical Engineering" replaced a one-credit hour course in the old curriculum so substantial design and curriculum integration can be implemented; this course was taught for the first time in Winter Quarter, 1996. Other lower-division curriculum ehancements include three new courses: (a) a one-credit hour, sophomore-level laboratory course integrating materials, manufacturing and design was implemented for the first time in Fall Quarter, 1995; (b) a two-credit hour, sophomore-level course employing writing to explore the social impacts of technology and

engineering ethics will be implemented in Spring Quarter, 1996; and (c) a two-credit hour, sophomore-level "Introduction to Design" will also be implemented in Spring Quarter, 1996.

METHOD

Course development of ME125, "Introduction to Mechanical Engineering," is guided by a recent report on engineering education for the 21st Century[2]. The report, "Engineering Education for a Changing World," calls for, among other curriculum objectives, team skills, communication skills, leadership, an understanding and appreciation of diversity and different cultures, a multi-disciplinary perspective and a systems perspective, and a commitment to quality, timeliness and continuous improvement. Service Learning provides the medium through which students enrolled in ME125 will have the opportunity to encounter these experiences and to develop these skills. (The same report also calls for, as an action item, engineering colleges to form partnerships with K-12 schools and with the broader university community.)

Service Learning is defined as a method under which students learn and develop through active participation in thoughtfully organized service activities that meet the needs of a community; is integrated into and enhances the academic curriculum of the students; and is coordinated with K-12 schools and institutions of higher learning[3]. In ME125, Service Learning is chosen as the strategy for first-year students to practice the design process. The design customers assigned to the student design teams are middle-school teachers. The products of the design projects are instructional modules in the form of a workbook, and manipulatives that will be designed and developed by the design teams. The knowledge base of the design project is middle-school mathematics and science, so the "analysis" part of the design process will be less of a burden for first-year students and they can focus their energy on the "creativity" part of the design process. (There are many everyday examples of engineering that are described by middle-school mathematics.) Interaction with middle-school teachers and students will provide the opportunity for first-year engineering students to appreciate diversity and practice their communication skills.

In carrying out their design projects, engineering students will apply the successful and well-proven strategies of hands-on learning and a thematic approach to instruction[4, 5] in designing the instructional modules. Since a mathematics/science teacher and a language arts/social studies teacher are assigned to each design team, ME students must create cross-disciplinary ideas for the instructional modules that are integrated. Through this practice, first-year engineering students will see, early on in their career, that a successful design is multi-disciplinary and requires a systems approach. They will be exposed to these experiences by participating in two case studies prior to carrying out their own design projects. Students enrolled in ME125 will be provided with a detailed schedules of the design project timeline. They will have the opportunities to practice scheduling in creating a team schedule to meet project timeline. Through this practice, they will have the opportunity to appreciate the importance and relevance of timeliness in each step of the design process.

In addition to providing a real-world, social context to practice the design process, Service Learning also gives first-year engineering students the opportunity to participate in activities to address a common concern among engineering faculty members. A 1992 National Science Foundation report identifies one cause for this concern to improve problem-solving skills and the ability to integrate mathematics and science concepts among lower-division engineering students: An analysis of tests administered in high school "revealed that they stressed memorization rather than high order thinking. Only five percent of test items required more than mere memorization of facts"[6]. In Mobile County, a lack of classroom resources and staff training are obstacles to implementing the well-proven strategies of employing hands-on learning and a

multi-disciplinary approach to stimulate student interest and develop higher-ordering thinking skills. Middle-school teachers are chosen as the customers for the design projects because middle-school students are a critical age group because elementary-school students are enthusiastic about mathematics[7]. When first-year ME students see the products of their intellectual effort serve a need in the community and a mission of the College of Engineering, they will hopefully gain self-confidence and relate to the engineering profession. These indicators have been identified as reflecting the profile of a first-year engineering student who will be successful in a college career[8].

IMPLEMENTAION PLAN

Activities for ME125, "Introduction to Mechanical Engineering," aim toward achieving the following objectives for students:

• Demonstrate the elements of a successful design

• Identify with the engineering profession

• Design an instructional module/workbook

1. Role of Teacher Participants

Recruitment and selection of teacher participants was carried out in October and November by the Teacher Coordinator of SECME (Southeastern Consortium for Minorities in Engineering) from the Mobile County Public School Systems (MCPSS). Two-teacher teams from ten schools were selected with half the teacher teams serving as customers for the design teams in Winter Quarter and half in Spring Quarter, 1996. Of the ten schools involved, eight (8) are located within the City of Mobile and two are located outside the city. Two of the schools are magnet schools, and two schools are participants of an expanding Model Middle School program in MCPSS. Each teacher participants is provided two (2) substitute-teacher days and a stipend for their involvement.

Orientation for all teacher participants took place in early December, 1995. At the orientation, a description of the Service Learning project and ME125 instructors' expectations of teacher participants were presented, both in the form of a one-page questions-and-answers information sheet as well as a short presentation and discussion session led by the authors of this paper. These expectations will include meeting with the design teams, implementing and evaluating the instructional modules in their classroom, attending final project presentation, and participating in an evaluation survey of the Service Learning project. Teacher participants' expectations of the project and ME students were surveyed in a Feed Forward Form at the conclusion of the orientation session.

At the beginning of the academic quarter in January, the teacher participants were given a schedule of the (8) days when they will be interacting with the four ME students assigned to them to work on the design project, plus the objectives for the meetings. Students fill out a meeting log after each meeting, which is then returned to the instructors. Other additional opportunities for interaction between ME students and middle-school teachers include two visits by ME student team members to middle-school classrooms to lead activities related to the design projects.

2) Instructional Workbook

The products of the design projects are instructional workbooks and manipulatives that student design teams will deliver to their teacher customers. Each workbook contains the descriptions of daily activities

(introductiory, developmental, and culminating) and the supporting materials for the activities that the teacher customer can use for a 5-day period to implement hands-on learning of mathematics and science in his/her classroom.

3) Course Description

ME125, "Introduction to Mechanical Engineering," was taught for the first time in Winter Quarter, 1996 to a class with enrollment limited to 20 students. The rationale for limiting enrollment for the first time is to ensure a sufficient pool of students to take the trailer section, which will be taught in Spring Quarter, 1996 and which hopefully will have fewer problems in course implementation. The 20 students are grouped into five (5) teams of four (4) students each. The course meets four times a week for 50 minutes for approximately ten weeks, and carries four (4) credit hours. A week-by-week description of ME 125 follows:

Week One

The Executive Summary of "Engineering Education for a Changing World"[2] will be read and discussed in class concerning course goals and objectives, and background for course design of ME125. Students will also learn industries' view of teaming; form into teams, and participate in two Team Building exercises and one exercise to develop a conflict resolution strategy for addressing potential teaming problems. Students will also be introduced to the computer support for the course (6 90MHz Pentium computers with Microsoft Office and AutoCAD), and learn how to send and retrieve messages from the network. Materials for teaming activities are drawn the report by L. Bellamy, *et al*[9]. Homework for Week One includes a one-page essay about a fellow team member, and a two-page essay about a ME faculty that the team members interview. A Pre-survey for student and course assessments will also be given as a homework assignment.

Week Two

Students find out about the various disciplines within the Mechanical Engineering profession. Activities include visits to the different laboratories (instrumentation, materials science, and thermal/fluids) that support upper-division courses, and presentations/demonstrations by other ME faculty members. Each team is assigned to interview one recent ME graduate who is an engineer in the Mobile area, and make oral and written reports.

Week Three

The activities to teach creativity and problem solving are drawn from Fogler and Leblanc's book, *Strategies for Creative Problem Solving*[10]. The major steps to a successful design will be described and classroom discussions conducted for each. Two key steps to completing the design -- problem definition and brainstorming ideas -- will be stressed. Classroom and homework assignments highlighting each of the design steps will be given to the design teams. Class time will be allotted for each group facilitator to report the results from the assignments. In this manner, results obtained by each group will be shared with the entire class. This approach has been successful in the past in a senior design course at this institution.

Week Four

Case Study #1 illustrates the use of a lever to design an instructional module for an eighth grade math class. Activities for ME students during Week #4 include designing and building a catapult, and applying a spreadsheet program to model the flight of a project fired from the catapult. Activities and course materials for this week are drawn from the work developed jointly by one of the authors (ET) and a SECME middle-school teacher from MCPSS, Maryann Husam of Azalea Middle School. On the last class day of Week #4, students receive a briefing on (1) the design projects; (2) the rationale for the design projects; (3) design project timeline, (4) elements of a successful design, (5) team roles and responsibilities, and (6) the elements to hold successful meetings.

Week Five

Students meet the design customers and gather information about them and their needs during the initial meeting on the first class period of Week #5. Case study #2, which uses a pendulum as the theme for an instructional module, is presented in the remaining three class periods. Homework for this week includes writing a first draft of the design problem statement. Another homework activity is each ME student design team lead an activity in a middle-school classroom about engineering -- engineering students talk about the reasons they decide to study engineering, and how to prepare for an undergraduate career in engineering. This activity must be led by at least two members of the design teams and extra credit is awarded when the presentation is conducted by three or all the design team members. At this meeting, ME students will gather their first-hand impression of the design environment. Students will then submit a report.

Week Six

On the first class period of the week, students are given instructions on literature research. The rest of the week is devoted to instructions on instructional design led by a faculty from the College of Education. This includes: (1) an overview on what motivates middle-school students, and activities on motivation, and (b) the essential components and techniques to implement cooperative learning; and (3) an overview of learning styles and self-analysis scales. Homework for this week includes writing a report on a subject of literature research, and showing the first draft of the design problem statement to the customer. Homework also includes completing middle-school visit and writing report on design environment.

Week Seven

Week Seven is devoted to identifying the design criteria and constraints, and brainstorming ideas. Each design team will have an opportunity to report its problem statement and objectives, and lead the class to identify the design criteria and constraints for its design project. For a homework assignment, student teams make an appointment with the instructor from the College of Education to write the instructional objectives based on the design problem statements. Another homework is meeting with design customers to present design ideas and to gather feedback.

Week Eight

Activities for the week focus on the development of design ideas, and preparing drafts for the instructional modules. Homework includes meeting with design customers to report on the designs they are going with and turning in meeting log, and writing a draft of the purpose and introduction sections of the Instructional Workbook, and daily activities.

Week Nine

Activities for the week focus on activities for the instructional module, building and testing prototypes, and revising final design. Homework includes one meeting with customers to gather feedback on worksheets, activities and lesson plans for the Instructional Workbook; and one meeting to present prototype and gather feedback.

Week Ten

Activities for Week Ten focus on finishing the design project and preparing for project presentation. Homework includes one meeting with customers to present draft workbook and gather feedback, and one meeting to lead activities based on the instructional module and gather feedback from middle-school students. Post-survey of ME students will take place after project presentation on the day of Final Exam.

EVALUATION

The design for the first segment of the evaluation, used to measure program impact, is depicted as follows:

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WINTER QUARTER (Group One) SPRING QUARTER (Group Two)

In words, two One Group Pretest/Posttest Designs were used in tandem. An instrument (described below) was given to two groups of approximately 20 ME 125 students at the beginning of the quarter and at the end of the quarter. The second pretest/posttest study (i.e., spring quarter) can be viewed as a replication of the first (i.e., winter quarter). Use of this design is superior to a single One Group Pretest/Posttest Design in terms of certain threats to internal validity (e.g., history) and statements of causality (because of replication on different participants). The design is, however, not as strong as a comparison group design. As described below, other instruments were used with the ME 125 students to collect additional information on program impact and various opinions and attitudes.

The data collection instruments assessed factors in the following areas: efficacy of engineering students in class work, engineering as major, and working with middle school teachers; attitudes toward school, engineering, Service Learning, and community service; abilities related to problem solving, computer skills, interpersonal interactions, and cooperative learning activities; and skill development in content and process knowledge.

To assess attitudes and efficacy, the pre and post instruments were divided into two sections. One was administered on the first day of class and then again at the end of the quarter; the second is administered in the third week of classes, when the students had acquired more information and practice to prepare for the Service Learning experience but had not yet begun the actual project (and also at the end of the quarter).

For the first instrument, measures were taken related to the following factors: school attitudes, career decision-making, attitudes toward engineering, and efficacy as a student, an engineering major, and a decision-maker. The items came from three sources: 7 items came from the Classroom Climate Inventory of Johnson, Johnson, and Anderson[11] assessing attitude toward cooperative learning; 30 items came from a survey used at the University of Pittsburgh[12] to assess attitudes toward engineering, efficacy in engineering, self-assessed study skills, and problem-solving ability; 57 items came from an instrument assessing self-efficacy and career indecision[13] and included the following factors: goal selection, planning, problem-solving, occupational information, and self-appraisal. The item formats were 4, 6, and 8 point rating scales and descriptive type questions. In addition to the above, the students were asked to define engineering, and to assess their confidence in the related academic areas of calculus, physics, chemistry, writing, speaking, and computers.

In the second instrument, items were directly targeted at attitudes and abilities in relation to cooperative learning group involvement, teaming with middle school teachers, and facets of the Service Learning project. Three instruments included 20 items from the Classroom Climate Inventory[11] assessing

attitude toward ME 125 and cooperative learning, 17 items by R.I. Kahn *et al*[14] assessing attitudes toward teaming and working with the public (middle school teachers), 9 items from the Michigan Organizational Assessment Questionnaire[15], 16 items from the Overall Job Satisfaction Questionnaire by Cook[16] assessing intrinsic and extrinsic attitudes toward the project and teaming, and 11 items from the educational requirements efficacy scale by R.W. Lent *et al*[17], assessing students' confidence in their ability to complete academic requirements for a major in engineering.

In addition to the two instruments, students were required to assess cooperative learning groups at the beginning, midpoint, and end of the project using the Team Cohesiveness Scale[18]. Data were also collected from the middle school teachers and the ME 125 instructors on their reactions and opinions. In short, we attempted to talk with all parties involved in the project using both quantitative instruments (for numerical ratings) and qualitative instruments (for in depth and process information). Finally, Goal-Free Evaluation techniques were used to determine unintended project outcomes that designers and evaluators may have overlooked.

Results of student and teacher assessment will be presented at the conference.

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