Int. J. Engng Ed. Vol. 17, No. 1, pp. 30–39, 2001
Printed in Great Britain.

0949-149X/91 $3.00+0.00
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A Report on Service-Learning and Engineering Design: Service-Learning's Effect on Students Learning Engineering Design in 'Introduction to Mechanical Engineering'*

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Service-learning is a form of experiential education in which students apply the knowledge and skills they learn in the classroom to carry out projects that meet a human or community need. Service-learning has been integrated into an 'Introduction to Mechanical Engineering' course to enhance learning of first-year engineering students and to meet the need for more resources in local middle-schools to promote active, hands-on learning of mathematics and science. Student assessment results over a three-year period demonstrate that service-learning is an effective strategy for first-year mechanical engineering students to learn and practice engineering design and teamwork, and to become aware of civic responsibility. Service-learning provides engineering students the opportunity and motivation to develop the 'softer' skills described in Engineering Criteria 2000 and complements the traditional approach to design projects, in which students interact primarily with technical personnel.

INTRODUCTION

SERVICE-LEARNING is a form of experiential education in which students apply the knowledge and skills they learn in the classroom to carry out projects that meet local human and community needs. Although it is relatively new in engineering education, service-learning offers an innovative strategy in meeting current trends in engineering undergraduate education while addressing the challenges of societal needs as a result of decentralization of government in the United States. This paper defines service-learning and presents the argument for its integration in educating engineering undergraduates to meet the societal challenges and needs of the 21st Century. The paper concludes by describing the results of student assessment over a three-year period in an 'Introduction to Mechanical Engineering' course, in which service-learning provides the context for students to learn and practice engineering design and teamwork.

WHAT IS SERVICE-LEARNING?

A driving force of service-learning is civic education by integrating community service into academic learning. Jacoby defines service-learning as [1]:

> . . . a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development. Reflection and reciprocity are key concepts of service-learning.

The goal of reflection is:

> . . . to promote learning about the larger social issues behind the needs to which their service is responding. This learning includes a deeper understanding of the historical, sociological, cultural, economic, and political contexts of the needs or issues being addressed.

Jacoby explains the concept of reciprocity as follows [1]:

> The needs of the community, as determined by its members, define what the service tasks will be. Service-learning avoids placing students into community settings based solely on desired student learning outcomes and providing services that do not meet actual needs or perpetuate a state of need rather than seeking and addressing the causes of need. Through reciprocity, students develop a greater sense of belonging and responsibility as members of a larger community. Community members being served learn how to take responsibility for their own needs and become empowered to develop mechanisms and relationships to address them.

Service-learning is well established in the humanities and social science fields, and in some

* Accepted 20 March 2000.

professional disciplines where clinical experience forms part of student learning. Campus Compact, a national organization of US university presidents who are committed to integrating community service into the undergraduate education experience, surveyed its membership schools in 1997 and found 243 institutions offering 4273 service-learning courses in all academic and professional fields, but primarily in the humanities and the social sciences [2].

A large-scale study in 1998 of the impact of participation in community service projects on student learning and development by Astin and Sax [3] shows that participating in service during the undergraduate years substantially enhances the student's academic learning and development, life-skill development, and sense of civic responsibility. A 1999 study by Eyler and Giles on service-learning involving 1500 students from twenty colleges found positive impacts on personal development, interpersonal development, tolerance, and connection between community and college [4].

SERVICE-LEARNING AND ENGINEERING EDUCATION

Current trend in engineering education in the United States

A paradigm shift in engineering undergraduate education is occurring in the United States. Engineering Criteria 2000, the accreditation criteria established by the Accreditation Board for Engineering and Technology (ABET), formalizes the incorporation of 'softer' skills into the undergraduate curriculum. ABET follows the calls to reform undergraduate engineering education by the American Society for Engineering Education (ASEE) and the National Science Foundation (NSF) in the mid-1990's.

Citing the end of the Cold War, a global economy, changes in student demographics, and information technology, ASEE and NSF published reports in 1994 and 1996, respectively [5, 6], that call for the incorporation of 'softer' skills into the traditional engineering curriculum to meet the challenges of the 21st Century. These 'softer' skills include [5]:

- team skills, including collaborative, active learning;
- communication skills;
- leadership;
- an understanding and appreciation of the diversity of students, faculty and staff;
- an appreciation of different cultures and business practices, the understanding that the practice of engineering is now global;
- an understanding of the societal, economic and environmental impacts of engineering decision.

In EC 2000, engineering programs are required to demonstrate that their graduates have, in addition to technical capabilities [7]:

- an ability to function on multidisciplinary teams;
- an understanding of professional and ethical responsibility;
- an ability to communicate effectively;
- the broad education necessary to understand the impact of engineering solutions in a global/ societal context;
- a knowledge of contemporary issues.

Design is at the heart of engineering; and any definition of engineering would include 'service to society' or 'meeting societal needs' as a mission of the profession. In carrying out a service-learning design project, students must often interact with people outside their socioeconomic groups and disciplines. Consequently, the engineering students will have the opportunities and motivation 'to function on multidisciplinary teams' and 'to communicate effectively,' which are EC 2000 criteria for student performance outcomes [7]. Therefore, service-learning provides an ideal context for engineering undergraduates to learn and practice design, and complements traditional engineering design projects, where students interact primarily with technical personnel.

Furthermore, in a service-learning design project [1]:

> . . . the needs of the community, as determined by its members, define what the service tasks will be Students develop a greater sense of belonging and responsibility as members of a larger community.

Therefore, engineering undergraduates will have an opportunity to develop 'an understanding of professional and ethical responsibility,' another EC 2000 student performance outcome criterion [7]. Finally, students develop 'a deeper understanding of the historical, sociological, cultural, economic, and political contexts of the needs or issues being addressed' through reflection in service-learning [1], therefore they will have an opportunity to gain 'knowledge of contemporary issues' and appreciate 'the broad education necessary to understand the impacts of engineering solutions in a societal context,' which are EC 2000 criteria for student performance outcomes [7]. Thus, service-learning can be an effective strategy in meeting the current trend in undergraduate engineering education, particularly in regards to EC 2000.

Some examples of service-learning in engineering

While it is a relatively new idea in engineering education, a small number of engineering faculty members have begun to integrate service-learning into their courses to address local community needs. Leah Jamieson's EPICS (Engineering Projects in Community Service) program at Purdue University uses service-learning to implement multi-year, cross-level design in the Electrical & Computer Engineering Department, where senior to first-year students work together on a team to solve community needs. EPICS's partners include K-12 schools, a children's hospital, and community-service agencies. A majority of the students cite the opportunity to obtain 'practical, real-world experience in engineering design' as their primary reason for participating in the EPICS program during the formative evaluations. In every semester, however, a significant number of the students also identify the opportunity to do community service as a major factor in their EPICS participation. In summative evaluation based on a survey of 153 students collected for three semesters from 1996 to 1997, students gave 'ability to work in a team' and 'understanding of the design process' the highest scores of 3.54 and 3.45 out of 4.0, respectively. 'Community awareness' received an average rating of 3.2 and 'communication skills' receives an average rating of 3.36 out of 4.0 [8].

Other examples of service-learning in Engineering and results of student assessment are described in [9], and include: John Duffy of the University of Massachusetts-Lowell who has adapted service-learning to teach solar-energy design as well as in senior mechanical engineering lab; C. Diane Martin at The George Washington University who uses service-learning in a course in a course on technology and society that is required for junior electrical engineering, computer engineering, and computer science students.

For the service-learning projects, students work in teams to carry out social impact analysis on the use of computers in community-service organizations, and they make recommendations to improve both efficiency and effectiveness in the use of computer systems to serve clients of the community-service agencies. Marybeth Lima of Biological and Agriculatural Engineering, Louisiana State University, integrates service-learning into an 'Introduction to Engineering' course in which her students design playground equipment for an elementary school. The Civil & Environmental Engineering Department of University of Utah, which has a focus on infrastructure and the environment, offers five service-learning courses to address infrastructure and environmental needs in Salt Lake City.

SERVICE-LEARNING IN 'INTRODUCTION TO MECHANICAL ENGINEERING'

Adapting and implementing service-learning into an engineering course can be carried out in four steps [10].

1. Match community need with course learning objectives: form partnership.
2. Create and implement solutions.
3. Evaluate for continuous improvement.
4. Reflect.

The adaptation and implementation of service-learning into an 'Introduction to Mechanical Engineering' course will be discussed in these four steps.

Match community need with course learning objectives: form partnership

In Fall 1993, the University of South Alabama (USA) Chapter of Sigma Xi sponsored a forum to discuss ways the USA faculty could contribute to improving mathematics and science learning in the public school system. A panel of teachers, principals, and supervisors told the USA faculty that resources to support active, hands-on learning are a high-priority need. The panel also identified the middle-school years – Grades 6 to 8 – as critical. The panelists stated that interests in math and science are high among elementary-school students but drop off in the middle-school grades, resulting in few high-school students taking the math and science 'gate-keeper' courses necessary for post-secondary studies in science, mathematics and engineering.

Also in Fall 1993, the faculty members of the Mechanical Engineering Department of the University of South Alabama undertook a self-study to evaluate the undergraduate curriculum to prepare for the next accreditation visit in 1999. At the time, the Accreditation Board for Engineering and Technology (ABET) was moving toward 'design-across-curriculum' as a criterion for accrediting engineering programs. The self-study team was also aware of calls for reforming the undergraduate engineering curriculum by the American Society for Engineering Education (ASEE) [5] and the National Science Foundation (NSF) [6].

At the end of the self-study, the ME faculty identified two areas for improvement in the first two years of the curriculum. First, students previously received little instruction in and practice of engineering design in lower-division courses. Second, the one-credit-hour Introduction to Mechanical Engineering, which was taught in the Fall Quarter of Year One's curriculum, was insufficient to include instruction on engineering design because of the format of the course – nine to ten meetings for fifty minutes each. As a result of that review, a new curriculum was put in place beginning Fall 1995 in which three new courses with substantial design content were introduced into the first two years of the curriculum. A four-credit-hour Introduction to Mechanical Engineering was one of the new courses introduced, and it has the objectives of introducing the engineering design process, teamwork, and communication and computer skills to first-year students.

The community need for more resources to support math and science learning in the middle schools of the local school system converged with the learning objectives of Introduction to Mechanical Engineering. Because many interesting, everyday examples of engineering are described by middle-school mathematics and science, the knowledge base for the service-learning design projects will be less of a burden to first-year ME students so they can focus on the 'creativity' and 'process' part of the design project.

Once the community need was matched with the learning objectives of Introduction to Mechanical Engineering, the existing partnership between the College of Engineering and the SECME (Southeastern Consort for Minorities in Engineering) program of the local school system was used to recruit the teacher partners.

Create and implement solution

The Introduction to Mechanical Engineering course has many of the same features of successful, model Introduction to Engineering courses described in ASEE publications [11–14], except that service-learning provides the context for students to learn and practice engineering design, teamwork, and communication skills. For the service-learning projects, a team of a math teacher and a science teacher is paired with a team of four or five engineering students. The teacher participants serve as clients to the engineering student design teams, which are tasked with the design and production of 'hardware' and 'software' that meet the needs and specifications of their clients to enhance the instruction of mathematics and science in middle schools.

The teacher partners for the service-learning projects are briefed at an orientation about the project, its timeline, and the partners' roles as well as the instructor's expectations of them. The teacher partners' expectations of the instructor and the engineering students are also surveyed at the orientation. The instructor meets with the teacher partners at the end of orientation to discuss the service-learning projects to ensure that their classroom instructional needs correspond to open-ended design problems for engineering students. The teacher partners serve as 'customers' to the engineering student design teams by stating their needs and specifications, and by providing feedback to the engineering students during the design phase.

During the first three weeks of the course, students receive instruction on engineering design through case studies and on teamwork using the materials of Bellemy, et al. [15]. The engineering students receive a memo from the instructor in Week 3 of the course identifying their clients and listing a general statement of need. The engineering students are then guided by the instructor in the last seven weeks of the quarter to complete the service-learning design projects. From interviewing their teacher clients, the engineering student design teams develop a deeper understanding of their clients' needs. From visiting the middle school and researching the state guidelines on math and science instruction, the engineering student design team identifies the specifications and parameters for their design project, which must address content, process, and habits of math and science learning. The engineering students then brainstorm solution ideas and, with input and feedback from their clients, they evaluate, select and implement the solution. To make the service-learning design projects more realistic, each engineering-student design team is given a budget of $50.00. The engineering students are required to demonstrate the 'hardware' and 'software' they have designed and produced to their clients, and to gather their feedback for evaluation before writing the final report. To complete the design project, each engineering-student design team presents to the teacher clients a manual together with the hardware produced. The engineering-student design teams are also required to submit a report to the instructor and make oral presentation. The service-learning design project constitutes 50% of the final grade for the course: written report (25%) and oral presentation (25%).

Some examples of the service-learning design projects produced by students enrolled in Introduction to Mechanical Engineering are:

- Pencil rocket launchers and a simple sextant to measure the height of rocket's flight were designed and produced for an after-school SECME program. The activities demonstrate a practical application of 'ratio' – in this case, slope – and the use of a look-up table. Engineering students also delivered a manual to the teacher clients which contains a history of rocketry.
- A flush-toilet was designed and produced to demonstrate the engineering concepts of lever and gravity-feed, and mathematical concepts of volume and the units for volume measurement, and algebra. Middle-school students use the flush-toilet to collect, graph, and analyze data.
- Tools and activities to investigate the math and engineering concepts behind the game of bowling were designed and produced. Middle-school students collect and graph data; apply the 'ratio' concept; and practice spatial visualization.
- Tools and activities to investigate surface-area-to-volume ratio and its manifestation in the natural world were designed and produced. Through the activities, middle-school students practice the lab skills of measuring and collecting data and descriptive writing, and apply the concept of surface-area-to-volume ratio.
- Activities based on the construction of the Pyramids of Giza were designed and produced. Middle-school students practice skills in measuring and collecting data; apply the concept of ratio to solve problems; and practice the skills of constructing a mathematical model.
- A windmill and an anemometer were designed and produced so middle-school students can use the instruments to collect data to investigate wind speed and wind energy.
- A Solar cooker, a model greenhouse, and a support for a solar panel were designed and produced to equip an outdoor classroom at a middle school.

Table 1. Grade distribution of service-learning projects 1995–1998

Grade	Written Report	Oral Presentation
	(evaluated by instructor)	(evaluated by another faculty other than instructor)
A (90–100%)	51 students (53.1 %)	53 students (55.1%)
B (80–89%)	32 students (33.3 %)	24 students (25%)
C (70–79%)	6 students (6.3%)	9 students (9.4%)
D (60–69%)	2 students (2.1%)	6 students (6.3%)
F (<60%)	5 students (5.2%)	4 students (4.1%)

- Equipment and activities were designed and assembled to support an after-school science club, where middle-school students collect data to observe and verify Newton's principles on force, motion and energy.

EVALUATION

There are three learning objectives for Introduction to Mechanical Engineering to evaluate.

Learning Objective #1: Students will demonstrate knowledge and practice of the engineering design process

This objective is assessed by a written report, which is evaluated by the instructor, and by oral presentation, which is evaluated by another engineering faculty member other than the instructor. The oral presentation is evaluated based on the following criteria:

- overall design (30%);
- clarity of presentation (30%);
- use of visual aid (20%);
- teamwork (10%);
- answering questions (10%).

The individual scores of students concerning the written report and oral presentation are calculated from the team scores by a weighting factor based on peer evaluation of each team member's contribution and effort towards completing the design project.

The involvement of another engineering faculty member other than the course instructor to assess this learning objective provides 'objectivity' in evaluating student learning engineering design. The oral presentation evaluations and the written evaluations provided by the two engineering faculty members were quite similar; their assessment of 87 of 96 students, or 90.6%, were in agreement. The grade distribution for the 96 students enrolled in Introduction to Mechanical Engineering in the three academic years from 1995 to 1998 is shown in Table 1. Overall, 85.5% of the students received a grade of B or higher for the written report, and 77.1% of the students received a grade of B or higher for the oral presentation.

Learning Objective #2: Students demonstrate teamwork

The teamwork process is tracked by minutes of meetings kept by the design teams, which allow the course instructor to follow progress in the design projects and the division of labor among team members. Attitudes of students about teamwork are evaluated by pre- and post-surveys and written comments during Years 1 and 2, and by a retrospective survey and written comments in Year 3.

The results for Years 1 and 2 (1995–1997) showed some inconsistency between the quantitative assessment (pre- and post-survey using Likert-type scales) and the qualitative assessment (responses to open-ended questions). These differences could be attributed to [16]:

- students at the beginning of the quarter having less awareness of the issue to rate themselves accurately;
- students tending to rate themselves high (ceiling effects) or in socially desirable ways in pre-survey;
- small sample size and non-random selection.

As a result, the approach to assessing student attitudes on teamwork was modified in Year 3 using an instrument that is more qualitative in nature.

In Years 1 and 2, when students were asked to list three skills obtained from the service-learning design project in the open-ended-question part of the post-survey, teamwork was mentioned approximately twice as often as any of eleven other skills. Teamwork skills cited by the students include:

- cooperative learning;
- the ability to communicate with team members;
- recognition of roles within the group;
- working with others;
- sharing ideas and working in a group;
- designing a project to suit others;
- importance of total group involvement.

In Year 3, students filled out a mid-term evaluation in Week 3, after they were assigned the design project. Concerning the learning objective on teamwork, students were asked to answer the following question #1. In the post-survey, the students were asked the same question plus question #2 on teamwork. These questions are:

1. You have recently completed your design project involving work with school teachers to design equipment that can be used in math and science education. What tools and skills did you acquire in the ME 125 (Introduction to Mechanical Engineering) course that helped you to complete the project? Specify what they were and how they helped you.
2. Answer the five questions below on a separate sheet. Please explain your answers:

a) What was the best part of working on the project as a team? What was the worst part of working as a team?
b) How did your team get along?
c) Did people carry out their assignments?
d) How relevant is doing work in teams to engineering?
e) If you had a choice, would you rather do the project working with a team or by yourself?

In the mid-term survey of Year 3, only 10 of 13 students returned the pre-survey, giving a response ratio of 0.77. There was a diversity of responses to the question that asks the students about the skills and tools they thought would help them with the project, and only one student mentioned teamwork. In the post-survey of Year 3, all 13 students participated (response ratio = 1.0); two students mentioned teamwork in response to the same question.

The following responses were recorded for the five questions about team and group processes in the post survey:

a) Three students mentioned a reduction in work load as being a positive aspect of working in a team; three students said that the solution that the group arrived at was better than what could have been accomplished alone; two students said having the help of others was a positive element; two mentioned the importance of learning about alternative perspectives about the problem; one student mentioned meeting new people; and one student said the best part was that the group worked well together. Negative elements of working in a team were less varied. Six students mentioned that scheduling was problematic; three students mentioned arguing and dissension as a problem; one mentioned that he/she did not like depending on others; one student mentioned the absence of a team member at a meeting was a negative; and one student had nothing negative to say.
b) All thirteen students responded that the members of their teams got along well.
c) All students indicated that their team carried out their assignment
d) Twelve students stated teamwork was very relevant, with one of them going so far as to suggest that teaming skills were one of the most important skills that an engineer could possess. One student did not respond to this question.
e) Twelve students indicated they would rather work in groups with one student stating he/she would work in a group if he/she could choose the team members; one student indicated that he/she would work alone. Generally, working in a team was viewed as a positive, and many advantages were cited, such as time savings, exposure to multiple viewpoints, and better solutions. Only two students seemed to have some reservations about working in groups: one wanted to pick his/her team members, and one student mentioned that he/she did not like feeling dependent on others for his or her grade.

Learning Objective #3: Students self-reported levels of community-civic responsibility will increase

The changes in student attitudes regarding community-civic responsibility as measured by pre- and post-survey are positive but small in Years 1 and 2. The results of this quantitative assessment suffer from the same weaknesses as described above for student attitude regarding teamwork. In the open-ended responses of post-survey, students listed benefiting society as a definition of engineering, along with problem solving and design. Benefiting society was either the most or second-most important, according to student responses.

It should be noted that one student in Winter 1996 objected to the community-service nature of the design projects and organized a complaint to the department chair. Despite the complaint by one student, which might have swayed the opinions of some students, the majority of the student comments regarding the service-learning projects and the course were very positive. For example, fourteen out of eighteen students in Winter Quarter 1997, submitted written comments. Of the fourteen comments, there were ten positive comments about the course; three complaints about the team selection process but two of the complaints also include positive comments about the course; and one negative comment about the amount of writing involved. For Spring Quarter 1997, fifteen of eighteen provided comments. There were twelve positive comments about the course, one suggestion ('Change the project to high school student so we could delve deeper into more complex math concepts'), and two negative comments ('the number and timing of project' and 'the amount of writing in the course'). Some examples of positive written comments for Winter, 1997 are listed here:

- 'I had a great time! The hardest work you will ever love.'
- 'Keep trying hard to do something productive for the community.'
- 'Excellent class that prepares ME students for the real world.'
- 'I learned a lot from this class, like organization, communication, and how to get on your feet'; 'Most enjoyable class at USA.'

- 'I really was impressed with the complexity of this freshman level course. Students are introduced to the design process, required to write reports, and communication is emphasized. Without those items, engineering will not take place.'
- 'I enjoy this class and also able to learn a lot of things.'
- 'I really learned a lot from the class. I think my lecturer motivated me a lot.'

In Year 3, this learning objective was assessed using an instrument that was more qualitative in nature. In the mid-term survey, students were asked to answer the following questions:

1. You have recently started your design project involving work with school teachers to design equipment that can be used in math and science instruction. How relevant do you think the project you have begun is to your training as an engineer? What makes it relevant (irrelevant)?
2. How has your experience with the project so far changed your ideas about community service? If it has changed your ideas, explain how. If it has not changed your ideas, why not?

In the post-survey, students were asked to answer the following questions:

1. You have recently completed your design project involving work with school teachers to design equipment that can be used in math and science instruction. How relevant do you think the project you have completed is to your training as engineer? What made it relevant (irrelevant)?
2. How has your experience with the project changed your ideas about community service? If it has changed your ideas, explain how. If it has not changed your ideas, why not?

In the mid-term survey of Year 3, only ten students returned the survey, and nine of the ten students mentioned that the project modeled the processes a professional engineer would engage in when working on a design project in the real world. The student who did not mention design process talked instead about the project as a potential builder of his/her competence in taking on future projects. Only one of the ten students in the pre-survey stated the project had changed his/her view about community service because he/she was learning from social activities to become a good and reliable engineer. One student mentioned he/she had not realized that community service can be fun. Two of the students said the project made them realize how important engineers are to society and made them excited about being engineers. Several said they have always liked community service because they enjoy being able to help others in general. One student mentioned he/she would not have engaged in this type of activity without the class assignment and would have missed out on a good experience. On the other hand, another student stated, 'I don't consider what we're doing to be community service since we're doing most of the work in the library and such facilities.'

All thirteen students participated in the post-survey. All students mentioned that the project gave them an experience that helped them learn about design in practice. Some of the comments regarding relevance were:

- 'Doing an actual project better prepares me for the future.'
- 'I learned about working with clients.'
- 'The project shows how important team effort is in engineering.'
- 'I used many engineering principles to complete the assignment.'
- 'If I do my best, I can have fun too.'
- 'The project enhanced team skills and introduced us to specifications and other design related criteria.'

Eight of the thirteen students reported they were already positive and remained positive about community service, and three students actually reported they were now more positive about community service. One student stated, however, that he or she would only do it if required. One student did not respond to this question. Some of the student comments are listed here:

- 'It has changed me a lot because I believe each individual can be productive in society if he wants.'
- 'I used to not believe in community service, but now I believe I should do more. Universities need to do more too.'
- 'My ideas about community service are basically the same. I wouldn't do it unless I had to. Although when I have done it, I feel better about myself.'
- 'By helping others, you receive gratification.'
- 'Community service is better than I previously thought.'

The results of the survey indicate that, with the exception of one student, most students were already positive about community service and three students became more positive. Thus, at the very least, students' positive views of community service were maintained and may even have been strengthened after the course was completed.

While there was no formal mechanism in place to evaluate the teacher partners as a follow-up, a number of them wrote unsolicited letters about the service-learning projects. For example, in Spring, 1998, three of the four teacher teams wrote letters, and their comments are summarized below.

> We are writing to tell you how pleased we were with the presentation made to our students by Chris Pryor and Rachel Deignan. The presentation went smoothly and had a variety of presentation mediums so that all students could understand. . . Chris and Rachel answered all questions presented by the students.

> They did an excellent job in presenting and we enjoyed the variety of materials they incorporated into the session. We could not be more pleased with the results!!!! Chris and Rachel have even agreed to return and conduct our stress tests when we have completed the project. Thank you for a job well done!!!!! (Yolanda Sibley and Cathy Zevac, Phillips Preparatory School)

> We are writing to commend the work done by your students. The project that they built will serve many students and teachers for years to come. We truly appreciate the time and consideration that they put into these projects. We will never know the full impact this will make on our students. As teachers, we cannot begin to tell you what it means for us to have any help with materials and especially the special expertise afforded us by your students. Not only were the projects absolutely perfect for our teaching methods but the attitude with which your students entered and completed this project was outstanding. Their willingness to help was most unusual and we are grateful to have worked with them. We want to thank you and the university once again for your concern and contribution. (Trudy Cunningham and Adell Puckett, Scarborough Middle School)

> We gratefully appreciate all the work the University does to help the school system. The students did a wonderful job at our Physics Fair. They were very organized and worked well with the students. Adams Science Club members thoroughly enjoyed working with them. We hope to get the opportunity to work with the University again in the future. (Keli Myers, Daphne M. Phillips, Daphne Elms, Adams Middle School)

REFLECTION

Reflection is that component of service-learning that distinguishes it from other forms of experiential learning in engineering, such as project-based instruction, but it is also the most challenging to engineering faculty. In reflection, students think about their learning experience with the goal of increasing community awareness and citizenship. As such, service-learning meets an objective for educating engineering undergraduates for the 21st Century – 'increase social awareness' – that is championed by a former ASEE president, Eleanor Baum [17].

Because most definitions of engineering include 'service to society' and 'meeting societal needs,' the reflection component of the service-learning projects in ME 125 focuses on this role of the engineering profession. Course materials for reflection are taken from a chapter of *Studying Engineering: A Road Map to a Rewarding Career* [18], a textbook for the course. The author, Raymond B. Landis, identifies 'giving something back' as part of the development of engineering students. In one assignment, students wrote short answers to five questions concerning whether their design projects meet Landis' definition of 'giving something back,' and how the service-learning projects could help or hinder their own development. Students were also asked to write a paragraph on how to communicate to middle-school students – the eventual end-users of their design efforts – concerning the type of advice they would like to have heard from a college student, assuming they were the middle-school students. Though not mandatory, some of the engineering students made presentations to middle-school students as part of National Engineers' Week celebrations. Students also wrote essays on the engineering profession, the engineering community, and ethics.

In their essays, all students stated that the service-learning projects meet Landis' defintion of 'giving something back.' All the students also stated that the service-learning projects helped in their development, citing engineering design, teamwork, and communication skills as reasons. Regarding whether the service-learning projects would hinder their development, a few stated that it would hinder their development only if they over-do it or if the projects took time away from studies. Most students suggested taking as many math courses as possible in their advice to middle-school students.

A few students visited middle-schools during National Engineers' Week and wrote about their experience. For example, a student wrote that he was initially hesitant to visit a middle-school because he was concerned about public speaking, but the experience empowered him because he discovered that he enjoys and can be good at public speaking. While there is no concrete evidence that the service-learning project was the direct cause, this student was active in representing the College of Engineering in speaking to area high- and middle-schools about studying engineering.

CONCLUSIONS AND RECOMMENDATIONS

Service-learning combines academic coursework and community service. Previous studies have shown positive impact of service-learning on a variety of cognitive and affective developments of students, many of which match Engineering Criteria 2000, the new accreditation criteria of ABET, such as those dealing with teamwork, communication skills, and awareness of professional and ethical responsibility.

Based on the results of student assessment over a three-year period in a Introduction to Mechanical Engineering course, service-learning has proven to be an effective strategy for a majority of the first-year students to learn and practice engineering design. More than 77% of the students received a grade of B or higher, based on independent evaluation by two engineering faculty members, and student comments about their service-learning projects were very positive. In carrying out a service-learning design project, students often have to interact with people outside their socioeconomic groups and disciplines, therefore, service-learning provides an ideal context for engineering undergraduates to learn and practice design to complement traditional engineering design projects, where students interact primarily with technical personnel.

For those engineering professors who are 'drawn to the profession precisely because of their love for teaching or for service – even for making the world a better place' [19], service-learning is an effective strategy to help engineering undergraduates develop a sense of community and citizenship. Society will gain too if more engineering faculty members implement service-learning into their course work, because many solutions to societal problems require the special knowledge and skills of engineering.

'At no time in our history has the need been greater for connecting the work of the academy to the social and environmental challenges beyond the campus,' E. Boyer wrote in *Scholarship Reconsidered* [19]. Thus, service-learning answers the call by ASEE's Green Report [5] to broaden the community base that engineering colleges should build partnership with. The Green Report states:

> A key element in the success of these efforts [engineering education in a changing world] will be partnerships: partnerships not only with industry, but with K-12 schools, community colleges, the broader university community, government, and among engineering colleges.

Scheduling and time conflicts between engineering students and community partners will always be a challenge in implementing service-learning projects. A large majority of students at the University of South Alabama work, and many of them are married and have children, and for the first-year students in Introduction to Mechanical Engineering, many of them have labs (physics, chemistry, engineering graphics) in the afternoon. One recommendation is to begin the service-learning project as early as possible, and inform both the students and their community partners that scheduling could be a hurdle, and to encourage them to be persistent and creative in making and keeping appointments.

A second recommendation is to recruit another engineering faculty member to evaluate the oral presentation of the service-learning design projects. Since the time commitment to evaluate oral presentations is small, many engineering colleagues would be willing to assist in evaluating the service-learning projects. This will provide more 'objectivity' in evaluating students learning engineering design and serve to promote service-learning.

Another recommendation is to use a qualitative instead of a quantitative approach based on pre- and post-surveys using Likert-scales to assess the impact of the service-learning experience on student attitudes on teamwork and community awareness. A qualitative approach, such as using a retrospective survey and written comments, can provide as much information in evaluating students as a quantitative approach, and would avoid 'ceiling effects' or students responding in socially acceptable ways that may not be indicative of their attitudes.

A final recommendation is to be prepared for students who do not wish to participate in design projects that are community-service based. The Ayn Rand Institute in California is now formally challenging the concept of community service and Service Learning in higher education. A number of essays listed in the Ayn Rand Institute website [20] attack community service, including one article that was published in *USA Today* that argues 'it is the opposing morality, 'that of selfishness', that enables man to achieve his own happiness' [21].

Acknowledgment—This work is supported by a grant from the Corporation for National Service Learn & Serve America: Higher Education, Grant # #95LHB00024.

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