

AC 2007-2621: SERVICE-LEARNING IN CORE COURSES THROUGHOUT A MECHANICAL ENGINEERING CURRICULUM

John Duffy, University of Massachusetts-Lowell

Professor of Mechanical and Solar Engineering. Faculty Coordinator of SLICE Program (Service-Learning Integrated throughout a College of Engineering), Coordinator of the Graduate Program in Solar Engineering, and Director of the Center for Sustainable Energy.

Linda Barrington, University of Massachusetts-Lowell

Service-Learning Coordinator for the Francis College of Engineering. She is a second career Mechanical Engineer, with over twenty years of human services management. She assists faculty in all five engineering departments to develop course-based service-learning projects to meet real community needs.

Cheryl West, University of Massachusetts-Lowell

Program Manager of numerous community-university projects. Work Environment Ph.D. candidate with major emphasis on work and environmental policy with minors in cleaner production/ pollution prevention and epidemiology. MS in community psychology.

John McKelliget, University of Massachusetts-Lowell

Professor and Chairperson, Department of Mechanical Engineering. Received his Ph.D. in 1980 in the UK, then was a Visiting Scientist at MIT, and has been at UML since 1984. He is a Senior Member of IEEE, a Member of ASME, and has been involved in the numerical simulation of thermal plasma systems for more than 25 years.

Eugene Niemi, University of Massachusetts-Lowell

Professor, Mechanical Engineering. Dr. Niemi has taught at the University for 40 years. His industrial experience is in steam turbine and missile design. He currently teaches courses in fluid mechanics, heat transfer, and aerodynamics. He is a registered professional engineer.

Sammy Shina, University of Massachusetts-Lowell

Professor of Mechanical Engineering.

Hongwei Sun, University of Massachusetts-Lowell

Assistant Professor, Mechanical Engineering Department.

Chris Niezrecki, University of Massachusetts-Lowell

Associate Professor of Mechanical Engineering.

Robert Parkin, University of Massachusetts-Lowell

Professor, Department of Mechanical Engineering.

Majid Charmchi, University of Massachusetts-Lowell

Professor, Mechanical Engineering. Director of the Heat Transfer Laboratory.

Peter Avitabile, University of Massachusetts Lowell

Associate Professor in the Mechanical Engineering Department and the Director of the Modal Analysis and Controls Laboratory at the University of Massachusetts Lowell. He is a Registered Professional Engineer with a BS, MS and Doctorate in Mechanical Engineering and a member of ASEE, ASME and SEM.

Service-Learning in Core Courses throughout a Mechanical Engineering Curriculum

Abstract

Service-Learning (S-L) has been shown to be effective on a large number of cognitive and affective measures for college students. S-L is a pedagogy in which student learning objectives and real community needs are met in a credit-bearing course. In engineering the integration of S-L into any courses, much less existing core courses in a curriculum does not match the penetration in other disciplines. The Mechanical Engineering (ME) Department at the University of Massachusetts Lowell has incorporated S-L projects into core courses so that every student has at least one required core course every semester with a S-L project that is either a required or elective part of the course. During 2005-06 fourteen core ME courses had S-L projects, and a required engineering ethics course also had S-L in addition to four elective courses. Nine of twelve ME faculty members incorporated S-L in those courses (more recently 12 of 13), in addition to 3 faculty outside the department teaching courses for ME students. This initiative is part of a college-wide effort to have all five undergraduate programs have S-L integrated into the core curriculum (ECE, ChE, CE, and Plastics E).

Courses and projects included, for examples, introduction to engineering for first year students (common to students in all five programs) who designed and built educational displays for the local national historic park, sophomore design lab with device development for student relatives or friends with disabilities, a dynamics course with safety analysis of many local playgrounds, a convective process course with the design of a water supply system for a village in a developing country, a statics course with a water tower design for another village (with the later two systems actually constructed in the villages the college has “adopted”), a machine elements course with four different S-L miniprojects, a ME laboratory course with the design of a measurement system to test local playground surface hardness, a heat transfer course with the analysis of energy efficiency of college classrooms, and finally several capstone course projects including a FIRST robot design/built with high school students, systems for remote villages, and an assistive technology device. In total 366 student-course projects were completed, ranging from extra credit to 100% of the course.

Assessment tools included several college-wide surveys and interviews of faculty, students, and community partners and student reports and presentations. The ME undergraduate student surveys from spring 2006 totaled 89 and do not include first year students because of the common courses. The average number of S-L courses taken was 2.4. To statements that S-L helped increase interest in learning, increase commitment to the community, improved writing and speaking skills, leadership ability, personal ability to “make a difference,” value of teamwork (among others) students recorded a range of agreement to non-agreement on a 1-9 point Likert scale. The averages were all 6 or above, disagreement ranged from 7 % to 14% and agreement from 60 to 75%. Most

faculty cited time as the biggest barrier to implementation. Improvements are planned with more student/faculty analysis of broader impacts.

Introduction

Service-learning is the integration of academic subject matter with service to the community in credit-bearing courses, with key elements including reciprocity, reflection, coaching, and community voice in projects (Jacoby, 1996)¹. Service-learning (S-L) has been shown to be effective in a large number of cognitive and affective measures, including critical thinking and tolerance for diversity, and leads to better knowledge of course subject matter, cooperative learning, recruitment of under-represented groups in engineering, retention of students, and citizenship, as well as helping meet the well-known ABET EC2000 criteria (a)-(k) (ABET, 2005)². The thesis here is that S-L spread throughout the core curriculum will be more effective than one intensive course, that a mixture of required and elective S-L is more effective than either one or the other, and that S-L could result in less coursework time than traditional programs satisfying ABET EC2000 criteria. Therefore, service-learning is being integrated into a broad array of courses so that students will be exposed to S-L in *every* semester in the core curriculum in the Mechanical Engineering Department as well as the other engineering departments in the college at the University of Massachusetts Lowell. The program is called SLICE, Service-Learning Integrated throughout a College of Engineering. This project builds on a long history of a variety of core courses with S-L by three faculty members within the EE and ME Departments.

Instead of the addition of more elective courses with S-L, which our students in general cannot afford, S-L projects were integrated into existing core courses. Also, the aim is to replace existing paper exercises in courses so that the overall workload will typically not increase for the students. If students are motivated to spend more time on S-L projects, they are free to do so and should learn more in the process.

The approach of S-L is consistent with the theories and empirical research of a number of leading educators and developmental psychologists, including Dewey, Kolb, and Kohlberg, as discussed by Brandenberger³ and Jacoby¹. The approach is also consistent with the recent change in paradigm in education from a focus on teaching to a focus on learning.^{4,5} Astin et al.⁶ found with longitudinal data of 22,000 students that service participation had significant positive effects on 11 outcome measures: academic performance (GPA, writing skills, critical thinking skills), values (commitment to activism and to promoting racial understanding), self-efficacy, leadership (leadership activities, self-rated leadership ability, interpersonal skills), choice of a service career, and plans to participate in service after college. “These findings directly replicate a number of recent studies using different samples and methodologies.”⁶ They found that S-L to be significantly better in 8 out of 11 measures than just service without the course integration and discovered “strong support for the notion that service learning should be included in the student’s major field.”⁶

Eyler and Giles⁷ in a classic study included 1500 students from 20 colleges/universities in a study of the effect of S-L. Service-learning was found to impact positively: tolerance

for diversity, personal development, interpersonal development, and community-to-college connections. Students reported working harder, being more curious, connecting learning to personal experience, and demonstrated deeper understanding of subject matter. The quality of placements in the community and the degree of structured reflection were found to be important in enhancing the positive effects, significantly so for critical thinking increases. They found that the "students who participated in service-learning differed significantly from those who did not participate on almost every outcome we measured."⁷ They summed up effective S-L principles in: connection (students, peers, community, faculty; experience and analysis); continuity (all four years; reflection before, during, after service); context (messiness of community setting is integral to learning); challenge (to current perspectives; not overwhelming); and coaching (opportunity for interaction; emotional, intellectual support).

There are varied opinions in the literature regarding whether S-L projects should be required or not. Eyler and Giles⁷ state: "Service-learning is often better academic learning and thus a legitimate requirement of an academic program...Students who are most in need of the developmental opportunities afforded by service-learning may be less likely to choose such course options voluntarily" (p. 182). In contrast, Clary, Snyder, and Stukas⁸ and Werner⁹ argue for voluntary S-L, based on research showing a required activity reduces intrinsic motivation. In questionnaires prepared by Banzert, Duffy, and Wallace¹¹, only approximately 20% of 260 student responses disagreed with the statement that service and academic coursework should be combined. Responses were correlated with age and gender (older students and women were more positive). Eyler and Giles⁷ had a similar percentage with their 1500 students in many disciplines.

In addition, S-L appears to have the potential to attract underrepresented populations in engineering through meaningful and experiential applications. Recent experience at Purdue indicates that voluntary S-L courses attract twice the percentage of women engineering students compared to the student engineering population¹⁷. Our own experience with voluntary capstone courses also indicates a similar overrepresentation of women (in one course 4 to 1 over 6 years) and older and more diverse students.

Service-learning itself is certainly not new, and S-L in engineering is not new. Some of the authors have been integrating S-L into courses at UML for about ten years. Oakes (2004)¹⁴ has a list of 33 universities that have S-L in engineering and describes a number of examples of S-L. In 2004-05 the National Science Foundation (NSF) funded ten programs to introduce S-L into engineering, which would add about 8 more universities to the list. EPICS (Engineering Projects in Community Service) started at Purdue and now includes 16 universities. The program involves elective interdisciplinary S-L courses that students can take from first year to senior year¹⁷. Tsang (2000)¹⁵ and Lima and Oakes (2006)¹⁶ describe more examples of S-L in engineering courses. Most of these S-L courses are capstone or elective courses with some first-year introduction to engineering courses. What is unique about SLICE is the integration of S-L into required courses in the core curriculum so that every student has at least one course every semester that has S-L either as a required or elective part.

A number of questions arise in this study: (1) Can enough faculty members be recruited who are willing to offer service-learning in their required courses to meet the goal of one S-L course every semester for every student? (2) Will a significant number of students be open to doing S-L projects? The SLICE program is a work in progress; however, there are some results so far to address these questions.

Approaches, Methods, and Results

The approaches and methods to develop the project and answer these questions are described below.

Faculty

ME faculty were recruited via personal contacts and through workshops offered in the summer and fall of 2004. All engineering faculty were invited. The summer workshop was an all day affair with presentations by Dwight Giles as well as community partners and breakout discussions. The second workshop was about 3 hours and focused on assessment, and again Dwight Giles presented. Dwight Giles is a well-known researcher in service-learning and was a consultant on the project. A planning grant and an implementation grant from NSF allowed faculty to develop S-L courses through minigrants and graduate student support, and a full-time S-L coordinator was eventually hired to provide a link to community partners. A motto for the faculty has been: “Start small rather than not at all.” The dean of the college, as well as the provost of the university, has provided significant moral and matching financial support for the project.

The courses in Table 1 below were offered in the academic year 2005-06 by 9 full-time ME Dept. faculty members and three other faculty from outside the department who taught courses for ME students. The majority of the projects represent about 10-15% of the course, with some, like capstone design, 100%, and one as extra credit worth about 3%. In the last column of the table the number of student-courses refers to numbers of students enrolled in the courses indicated. Note that some students took more than one S-L course at a time, so the total student-courses with S-L was 366 out of 708 total student-courses and, of course, represents more than the number of students in the ME program. The number of students in the second through fourth year of the program was approximately 150.

Table 1. ME courses with S-L in 2005-06

Yr	Course	F S	Cr	Course Title	Faculty	Activities	# S-L stdnts	# of stdnts
Common First Year Course								
Fr	25.107	F	2	Intro. to Engineering I	David Kazmer	Tsongas Center exhibits for K-12 illustrating principles of engineering with historical devices; and with GEARUP presenting/testing model bridges to middle school students & parents.	294	294

Fr	25.108	S	2	Intro. To Eng. II - ME	Sammy Shina	Design, and Temp. meas. in, solar ovens; for Grtr. LowellTech HS	13	69
So	22.201	F	2	Design Lab I	Robert Parkin	Design device to help relative/friend with disability with everyday activities	59	59
So	22.202	S	2	Design Lab II	Robert Parkin	Design/manufacture of assistive tech devices - some in Machine shop; some to senior Plastics	3	52
So	22.213	S	3	Kinematics	John Duffy & Faize Jamil	Local playground rides safety analysis	44	44
Jr	22.341	S	3	Conduct'n & Radiation	Hongwei Sun	Air conditioning system analysis for the Eng. Building	45	45
Jr	22.342	F	3	Convective Processes	Eugene Niemi Jr	Friction loss in pipes, water supply system design for village in Peru	49	49
Jr	22.361	F	3	Applied Analysis	John McKelliget	Statistical analysis of student questionnaire data	53	53
Sr	22.403	F	3	ME Lab II (Appls)	Peter Auitable	Develop method to test local playground surface hardness for safety, optional	12	45
Sr	22.423	S	3	Capstone	Sammy Shina; John Duffy	4 Groups: Village Empowerment Peru project, First Robot program with High Schoolers, Kenya solar project, & Assistive Technology project	15	46
Sr	22.425	F	3	Design of Machine Elements	Chris Niezrecki	Lowell canal lock and cleaning automation, WHOI re-design water sampling machine, & Peru water tanks	9	45
Sr	22.441	S	3	Thermo Applications	Majid Charmchi	Air-to-air heat exchanger for CMAA (1 group)	3	44
Sr	22.473	F	3	Design Theory	Sammy Shina	Design of Experiments for plastic windshield scraper molding, Plastics Department outreach	8	47
So	22.211	F	3	Mechanics (Statics)	(John Duffy)	Extra credit: tower design for water tank for village school	3	60

Total student-course projects 366 708
(with 50 students assumed for 25.107)

ELECTIVE/GRADUATE COURSES								
So	25.200	S	1	Community-based Engineering Design Project I	John Duffy	Canal trash cleaning devices for Lowell	1	1
Sr	25.401	S	3	Inter-disciplinary Engineering Capstone	John Duffy	Sand filtration water purification; improvements to water supply systems for Peruvian villages	2	2

Gr	22.504	F	3	Energy Systems Design	John Duffy	Feasibility study of PV and green building improvement for Lowell Technical High School	4	4
Gr	22.521	F	3	Solar Fundamentals	John Duffy	Analysis of monitored weather data for design of solar systems for villages in Peru; solar collector optimized layout for Lowell Tech feasibility study	8	8
Gr	22.527	S	3	Solar Systems Eng	John Duffy	Green building & solar designs for UTEC	14	14
Gr	24.532	S	3	Selected Topics in Energy	John Duffy	Green building S-L modules	1	3
Non-Engineering Courses								
Jr	45.334	F	3	Engineering Ethics (required for engineering students)	Gene Mellican	Examine opportunities for application of nanotechnology for our "adopted" Peruvian villages	80	80
Jr	45.334	S	3	Engineering Ethics (required for engineering students)	Gene Mellican	Research nanotechnology applications for Peruvian villages: pros and cons	45	45

A detailed description of the projects listed in Table 1 is included in Appendix A. Also the S-L projects in the first-year course (25.107) are described in more detail in Kazmer, Duffy, Perna (2006)¹⁰

The chart below (Table 2) indicates how the courses with S-L fit into curriculum by semester in 2004-05 and 2005-06 and in which the S-L projects are required (☺) and which are elective (☹).

Table 2. Distribution of ME courses with S-L by semester.

Year	2004-05	2005-06	No specific semester
FR 1	☹	☹	
FR 2	☺	☺	
SO 1		☹ ☺	
SO 2	☹ ☹	☹ ☹	
JR 1		☹	☹ Ethics

JR 2	☺	☺ ☺	☺ Ethics
SR 1	☺	☺ ☺ ☺	
SR 2	☺	☺ ☺	
Tech.Electives	☺ ☺ ☺	☺ ☺ ☺	

Students

A “pool” of student questions was developed in 2004 with S-L staff at MIT with the hopes that pooling of data could be started and that sharing of the data could help research on the impacts of S-L³. The questionnaire was revised by Cathy Burack for the spring 2006 and is shown in Appendix B.

The focus in this study on assessment is on expected long-term results, so individual course pre- and post-surveys were not necessarily taken. The results are pooled across courses. It is expected that it will take S-L in several core required courses before dramatic results are seen.

To the statement that service and coursework should be integrated, only 17 % disagreed in the 2006 post-survey, 48% agreed, with the rest neutral.

In the spring 2006 post survey, to statements that S-L helped increase interest in learning, increase commitment to the community, improved writing and speaking skills, leadership ability, personal ability to “make a difference,” value of teamwork (among others) students recorded a range of agreement to non-agreement on a 1-9 point Likert scale, and a majority agreed. On essentially all the opinion questions, the students show significant differences from neutral. Some results are summarized in Table 3.

Table 3. Post Spring 2006 survey ME students

	Mean	N	Significant Difference
Note: All significant effects (t-test, 5%) except where noted below.			
Number of classes with SL	2.4	81	neutral (mean minus 5)
Likert scale for statements below: 1 = strong negative impact; 5 = neutral; 9 = strong positive impact			
I can make a difference	5.8	80	.8
Increased interest in learning	5.8	83	.8
Increased commitment to community	5.7	82	.7
Improved writing and speaking	5.9	83	.9
Improved ability to find info	5.9	83	.9
Can evaluate information	6.1	81	1.1
Decision making skills	5.8	83	.8
Leadership skills	6.0	81	1.0
Value of teamwork	6.2	80	1.2
Ability to plan and carry out project	6.2	80	1.2

Likert scale for statements below: 1 = strongly disagree; 5 = neutral; 9 = strongly agree	Mean	N	Significant Difference
1. Service and academic coursework should be integrated.	5.8	81	0.8
2. Engineers should use their skills to solve social problems.	6.4	84	1.4
3. I feel that social problems are not my concern.	3.7	83	-1.3
4. People who receive social services largely have only themselves to blame for needing services.	4.2	83	-0.8
5. Social problems are more difficult to solve than I used to think.	6.0	85	1.0
6. The problems of unemployment and poverty are largely the fault of society rather than of individuals.	4.9	82	-0.1 (not significant)
7. I feel that I can have an impact on solving problems that face my local community.	6.0	85	1.0
8. I feel that I can have an impact on solving problems that face under-served communities internationally.	5.5	85	0.5
9. It is important to me personally to influence the political structure.	5.2	81	0.2 (not significant)
10. It is important to me personally to have a career that involves helping people.	5.5	84	0.5
11. I feel uncomfortable working with people who are different from me in such things as race, wealth, and life experiences.	3.5	73	-1.5
12. I have developed a close personal working relationship with at least one faculty	5.6	80	0.6

Dramatic results have been seen in courses involving clients with disabilities and involving work with indigenous people in remote villages in Peru. A few students in these courses have indicated in unsolicited comments that the experience has resulted in their changing the focus of their careers.

Community Partners

Community partners varied from the Lowell National Historic Park (LNHP) and the Cambodian Mutual Assistance Association (CMMA) to remote villages in Peru.

We had a structured survey for the community partners, and we also collected unsolicited responses from partners. The nature of engineering interaction with community partners

is more akin to that of a “customer” needing a product or system, rather than what appears to be more typical of social science S-L courses in which students are placed to work along side community service personnel. Feedback was generally positive from our community partners. For example, the Lowell National Historic Park indicated that the displays designed and built by students are equivalent to those for which museums typically would pay \$5000 to \$10,000.

S-L collaborations outside the United States have occurred with communities in Peru. Our experience with the Village Empowerment Peru Project provides an approach to international service. In this project, the College has “adopted” the small network of Peruvian villages where we have worked for the last nine years. Many design projects keep springing from the needs of the villagers, including projects in water supply, water purification, water pasteurization, micro hydro, photovoltaic, biomedical, and assistive technology devices, computers in schools, sterilizers, refrigerators, and radio transceivers. These projects lend themselves to work related to all the departments of engineering to say nothing of departments of nursing, physical therapy, languages, education, health education and work environment. The students and faculty typically share the knowledge gained from the local people and projects there with students who will work on projects but not necessarily travel to Peru. This focus on adopting villages can also provide continuity from the first year through senior years. Medical personnel in clinics in remote villages in Peru have said repeatedly that the solar-powered transceiver radio networks designed and installed by students with local help have saved many, many lives.

Nevertheless, with community partners we need to improve the follow through (actually delivering student designs and analyses and devices) and assessment. Increased communication with S-L involved faculty, students and community partners represents our first step in facilitating germane improvements.

Discussion and Conclusions

Based on the information and assessment data discussed above, we can address some questions related to the long-term goals of the project:

- (1) Can enough faculty members be recruited to offer service-learning in their required courses? Three quarters of the ME faculty members have incorporated service-learning into their courses (some faculty more than one course) by spring 2006. In the spring 2007 semester, twelve of the thirteen full-time faculty members have incorporated S-L into at least one course each. The strategic goal has been met of at least one S-L course available to every student every semester.
- (2) Will a significant number of students be open to doing S-L projects in several courses? Only a relatively small fraction of ME students (about 17%) report disagreeing with the practice of combining service and academic course work with 48% agreeing, with the remainder neutral in the spring 2006 survey. There are significant positive responses agreeing to perceptions of an obligation to make changes in society and personal empowerment to do so. Changes in basic

attitudes of both faculty and students toward the role of engineers in societal issues will take time to change, understandably.

In general, the overall goal of the project is on target. S-L integrated into core required courses seems to be achieving the hoped-for results, so far. The numbers of courses, students, community partners, and faculty involved is encouraging; now the challenge is to improve the quality overall of S-L projects and therefore their impact on the students, faculty, and community.

Acknowledgement

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Appendix A: Mechanical Engineering Courses with Service-Learning, 2005-06

Common First Year Courses

Introduction to Engineering I, 25.107, Fall 2005

Faculty: **David Kazmer**

Partner Organizations: **Tsongas Industrial History Center and GEAR-UP**

Partnership Description: As a joint venture between the Lowell National Historical Park and the University of Massachusetts Lowell Graduate School of Education, the Tsongas Center is an applied history center for primary and secondary students to learn about the American Industrial Revolution by experiencing history where it happened through hands-on activities. With a highly successful collaboration in the planning year, the Tsongas Center director and staff helped to define a new S-L project: To develop sturdy, working displays to occupy students in the Center's large lunch room. In addition to defining museum display specifications, the Tsongas Center staff assisted in grading the projects, judged the competition for which projects became permanent exhibits, and coordinated a reception for all the first-year students, hosted by the Center. *Project Description: Tsongas Industrial History Center Exhibits for K-12: Illustrating Principles of Engineering with Historical Devices.* In the Introduction to Engineering I class that all 294 first year students took together, Dave Kazmer set up a S-L project with the Tsongas Industrial History Center. The Center located in the Lowell National Historical Park, hosted teams of students engaged in design and construction of historical devices to illustrate principles of engineering mechanisms that have been employed historically in Lowell industries (e.g. waterwheels running textile mill machinery.) Tsongas displays were aimed at middle school students, and included appropriate mathematical formulas and definition of critical parameters for the working model. Several of the educational displays were selected to be on display in the Center, which over 60,000 school children visit each year.

Partnership Description: GEAR-UP, or Gaining Early Awareness and Readiness for Undergraduate Programs, is a U.S. Department of Education (DOE) funded grant program aimed at increasing the number of low-income students who attend college, by interventions that raise expectations and provide support for students to succeed. A 6-year math-focused GEAR-UP grant begun this past year targets 7th graders at the Robinson, Sullivan, Rogers, Butler and Stoklosa schools in Lowell and is administered through the UML Center for Family Work and Community (CFWC.) The parent liaison arranged with Dave Kazmer, to invite some of the first-year UML engineering students demonstrate an engineering design project for 7th graders and their parents. The ensuing demonstration turn out of 7th graders along with their parents and UML students, far exceeded the GEAR UP parent liaison's expectations.

Project Description: Bridge-building design project with GEAR-UP 7th graders and their parents. Also in the Introduction to Engineering I class, ten to fifteen UML

students volunteered to present and test the design and construction of toothpick bridges, which they had learned earlier in the semester. These UML students presented the bridge building project, then broke into teams of one UML student per one 7th grader and one parent. Together each team designed a bridge out of toothpicks. All of the bridges were then tested to see which were the strongest and how they failed. Time for discussion was included at the end of interaction and focused upon analysis of why the 7th graders thought the failures had occurred, and what were considered the optimal design features.

Learning objectives met by the S-L project were for students to:

- Illustrate principles of engineering with display devices
- Practice research and presentation skills
- Interaction with community partners and clients

Community objectives met by the S-L project:

Design interactive displays for the LNHP

**Introduction to Engineering II (Mechanical Eng.) 25.108, Spring 2006 Faculty:
Sammy Shina**

Partner Organizations: Greater Lowell Technical High School (GLTHS)

Partnership Description: This partnership built upon and strengthened previous partnership arrangements with GLTHS. Using feedback provided by GLTHS on last year's project, Environmental Science teacher, Deborah Gustafson provided planning time with the SLICE Coordinator and Teaching Assistant (TA), Robert Williams, to discuss renewable energy curriculum integration. In addition the partnership integrated use of classroom space, communication with UML engineering students and adaptation of the teaching modules for some of her classes and those of physics teacher, Paul Mears. UML students were organized and supervised by TA Robert Williams. UML Professor Sammy Shina helped to select three UML teams, in addition to attending student presentations at GLTHS.

Project Description: Renewable Energy Project. In the spring of 2005 UML graduate student Chris Lin developed teaching modules for secondary school children on principles of renewable energy which were piloted and evaluated in the classes of GLTHS science teachers Deb Gustafson and Carol Chisolm employing the idea of a solar greenhouse. This year, at Deb's request, the renewable energy project focused on designing and testing solar ovens. In lieu of a non-S-L assignment, 13 UML students from the Introduction to Engineering II (Mech. Eng.) class volunteered to plan and teach these modules in 45 min. class periods.

Learning objectives met by the S-L project were for UML students to:

- Function effectively in groups
- Participate in the design process within given constraints
- Present technical information to diverse groups using Microsoft PowerPoint
- Practice MatLab code input
- Use instruments and gages in a laboratory environment
- Graph data appropriately using Microsoft Excel and import into a Microsoft Word

document

- Write brief technical report using Microsoft Word
- Learn to motivate high school students through role model techniques

Community objectives met by the S-L project:

- High school students pay better attention to material taught by college-age students
- Introduction of renewable energy concepts
- Temperature readings taken on prototype solar oven
- Discussion and preliminary data and design analysis
- During another day's class period (without UML students) built and tested their own solar ovens

Design Lab I

22.201

Fall 2005

Faculty: **Robert Parkin**

Partner Organization: **Individuals with Disabilities**

Partnership Description: Students each identified a relative or a friend, or communicated with the Assistive Technology Program (ATP) to locate a client with a disability. Then each identified individual with a disability partnered with a student to specifically identify a challenge related to each individual's respective everyday activities. Students then designed and tailored devices to assist each client or individual. Individuals and their families and or caretakers reviewed design solutions and provided feedback on student designs and solutions.

Project Description: Examples of student projects included: developing specially designed bed rails for a mentally and physically challenged person, developing a special PC communication board for a friend, and specialized designs for a student's grandmother. The course emphasis was on introducing the use of computer aided design tools in the engineering problem solving process.

Course objectives met by S-L project:

- Introducing the use of computer aided design tools in the engineering problem solving process
- Design projects requiring the use of both wire frame and solid modeling tools
- Lecture and lab activities used to support project requirements
- Provided more in-depth understanding of computer aided engineering design and drawing

Community objectives met by S-L project:

- Student designs and products provided much needed mechanical devices
- Enhancement of quality of life and communication opportunities for a number of individuals

Design Lab II

22.202

Spring 2006

Faculty **Robert Parkin**

Partner Organization: **Individuals with Disabilities**

Partnership Description: The project discussed above for Design Lab I was continued throughout the following semester in Design Lab II to further explore designs and information generated during the previous semester.

Project Description: **Design and Manufacture Assistive Technology Devices.**

Sophomore Design Lab students identified a friend or family member with a disability and worked with them to design a device to assist them in an everyday activity. All first semester students (59) identified an individual, described a preliminary design in brief reports, revised their designs, and wrote a final report incorporating technical drawings and including customer feedback. Some designs were implemented by the end of the second semester. Three projects included an aluminum flip-top opener (machined aluminum in machine shop), a wooden handrail (installed for a student's grandmother,) and a plastic bracket to hold a communication device (Chat PC)

This was an introductory course in manufacturing processes covering the basic machine tool practices utilized in the manufacturing of a product. The objective of the course was to develop a broad understanding of manufacturing operations and their relationship to engineering product design. Students manufactured, fabricated and measured the accuracy of a mechanical assembly from design drawings, using lathes, milling machines, drill presses and other conventional processes.

Learning objectives met by the S-L project were for students to:

- Experience the design process, including working directly with a customer
- Present technical information using hand drawings
- Present technical information in 2D and 3D drawings using SolidWorks software
- Write brief technical reports using MS Word software and incorporating drawings
- Use machine tools to manufacture a device.

Community objectives met by the S-L project:

- Individuals with disabilities validated by having an everyday challenge taken seriously and having input into the solution
- Actual challenge resolved in cases where design was implemented

Dynamics 22.213, Spring 2006 *Faculty:* **Faize Jamil and John Duffy**

Partner Organizations: **Local playgrounds:** Pingree Park, Hamilton-Wenham Recreation Department, MA; Roudenbush Community Center, Westford; Holden Recreation Area, Holden, MA; and Heath Brook Elementary School, Tewksbury, MA, and others in the region.

Partnership Description: The overall goal of this S-L project was to provide students with an opportunity to apply theory and tools of engineering dynamics to an actual system in addition to opportunities to help local communities and integrate similar assistance for international communities (such as the Peru Village Empowerment S-L program). One of the suggested miniprojects was design oriented and more open-ended

to design a playground ride for kids with disabilities. Whereas, the other S-L miniproject suggested was a safety analysis and was more structured.

During the Kinematics course students were encouraged to work in groups of two to three persons for the S-L project. Each working group of students selected a different playground site. Students surveyed, analyzed and evaluated inherent safety hazards of playground designs, spacing, surfacing materials and equipment, turned in a joint group report. Students finalized their playground assessment and suggested improvements in a report that was shared with community partners (listed above). By the end of the course and S-L project, students reported increased awareness of engineering roles that contribute to increased safety capacity as a part of engineering design and assessment. Communities also received benefit through a specific set of playground recommendations for improved safety. These S-L design and safety assessments can better inform local decision-making processes regarding playground construction, improvements and helpful maintenance.

With their knowledge of dynamics, the students began to estimate the speed, forces, momentum, and potential injuries to children on various playground devices and recommend safety improvements. In this particular semester, none of the students in fact chose the design of rides for kids with disabilities as several had done the year before. Technical objectives of the miniproject included:

1. Estimating the maximum speed of children on various rides, including swings, slides (straight and helical), and merry-go-rounds.
2. Estimating the potential forces exerted on the children by the rides and by other children coming off the rides by exiting or falling off.
3. Estimating the impact of children hitting the ground from exiting or falling off the rides.
4. Informing the local community about maximum speeds, forces, and impacts on children on local playground equipment and the potential for injuries.
5. Suggesting improvements to the playgrounds in general (e.g., surface material, warning signs) and to designs of the rides (e.g., railings) to make them safer.

The learning objectives for this miniproject included:

- Application of the theory of kinematics to estimate the velocity, acceleration, forces, momentum, and impact on children of typical playground rides,
- Evaluation of the potential positive and negative impacts of the technology on the local community,
- Writing a report describing the analysis, results, conclusions, and suggestions of the miniproject. Composing a letter to parents and community groups with information important to them.
- Work on multi-disciplinary teams

Community objective:

- Improve the safety of local playgrounds

Conduction & Radiation Heat Transfer 22.341, Spring 2006 Faculty: **Hongwei Sun**

Partner Organizations: **UMASS Lowell Facilities:** Ball Hall Mechanical Room, Ball Hall Boiler Room, and UML Engineering Building Window System

Partnership and Project Description: Students in this course partnered with Mark Lukitsch, UML Facilities Manager, to investigate real industrial problems such as analysis and design of heating systems for UML buildings. Within the context of this partnership, teams of students collaborated to evaluate heat transfer conditions in several UML building locations, and analyzed ways to optimize existing thermal systems. Radiation networks were examined and integrated into the S-L projects. The ***Analysis and Design of Heating Systems for UML Buildings*** projects provided students with a real world concrete example in which they were able to identify existing problems within the engineering system, analyze thermal performance and developed a potential solution.

The S-L projects provided an opportunity for students to apply principles of radiation in their design projects, calculate costs (i.e., costs saved, fuel costs, design costs, window replacements). Furthermore, design projects integrated into the course provided useful information in terms of assessing heat loss, new design options and payback periods for such design improvements. In the case of the mechanical room assessment, students concluded that insulating pipes would provide a financially sound improvement to address the amount of heat released from the steam pipes in the basement of Ball Hall. **Window Improvement Project.** This project involved fifty-one students in redesigning the window system on the UML campus and proposing a new, improved window design. Students investigated energy saving strategies and practical application of heat transfer. However, in the window design project, students discovered that based on their analysis, a window replacement would not be cost effective. The objective of this project was to calculate the heat loss of the current window system of a building constructed during 1950, and to redesign the window system to minimize the annual heat loss in order to save money expended on heating over time. Through these S-L projects students became more familiar with the theory and application of steady state and transient heat conduction in solids; concepts and applications of Biot and Fourier numbers; principals of thermal radiation with application to heat exchange between black and non-black body surfaces; use of radiation networks (electrical network analogy); and surface radiation properties.

Convective Processes 22.342, Fall 2005

Faculty: **Eugene E. Niemi, Jr.**

Partner Organization: **Village of Muchipampa, Peru**

Partnership Description: **A Water System Design for Muchipampa** project was focused upon the design of a water delivery system to provide 1 gallon per minute from a spring-fed source to each of six homes spread over a distance of 500 meters in Muchipampa,

Peru. Muchipampa is a community that has about six families living in drought conditions for the past year. The village people have pleaded for UML S-L to put in a water supply system. There is a spring that has a flow rate of roughly one gallon per minute. There is a hill about 300 meters from the spring upon which a water storage tank of 1100 liters was planned for placement.

One of the student-designed systems was installed in Peru during Dr. Duffy's June 2006 trip to the village. This implemented project served to provide a water supply to homes normally living in drought conditions. Deliverables for the Peruvian community now include an installed water supply system consisting of a pump, storage tank, piping, and control valves. The Muchipampa community also participated in community-based discussions and decisions as to the best location for installing the water system. Course objectives met by this S-L project included design project in piping system design. Students and faculty also expressed an appreciation for a chance to work on a real world project that helps people, rather than a "paper design" only.

Project Description: Students worked in teams to meet project and course objectives. A water pump was identified and selected to deliver water. Objectives of the design were to meet requirements while minimizing total system cost (piping, tank, and pump, combined). Since the pump was planned to be solar powered, minimizing electrical costs was not considered as critical as would ordinarily be the case in such a design process. Student teams were required to identify: piping system length; pipe diameter and material; number of elbows, tees, valves, unions, etc.; head loss in system and total head delivered by the pump; pump specifications (manufacturer model number, output, power required, etc.); and cost of material and equipment.

Students worked in teams of six students each and self selected group members, as well as a group leader. The group leader was then responsible for overall coordination of the project, calling meetings of the group, etc. At the end of the project, all group members were required to analyze performances of each group member involved, including themselves, on a written evaluation sheet. Projects were finalized in a formal report with all design specifications, calculations and or discussions to support choices made, catalog or vendor data as required, and computer design of the final design. Design iterations were also included in appendices. The final design was installed in the Peruvian village.

Learning objectives met by the S-L project were for students to:

- Experience the design process, including the opportunity to apply theory and tools of convective processes to an actual system, and opportunity to help a remote village
- Estimate losses (friction loss factor), optimal diameter of pipes, pipe selection, maximum pressure in pipes, and loss in different joint or connections such as elbows and valves
- Write and present technical information reports

Community objectives met by the S-L project:

- Enhanced health and quality of life for a remote village in Peru

Applied Analysis, Mathematical Methods 22.361, Fall 2005 Faculty: John McKelliget

Partner Organization: SLICE Project

Partnership Description: Students in this course and S-L project applied statistics to the independent and dependent variables of the service-learning questionnaire for students to test relationships between variables and items on the anonymous surveys completed from 1997 to 2004. In this course and S-L project, students applied their knowledge of statistics to provide analysis and evaluation of questionnaire results. The first part of the survey inquired about general student demographics (independent variables). The second part of the survey inquired about student opinions relative to their S-L experience.

Project Description: Students selected independent variables that may have affected dependent variable outcomes. A regression analysis was conducted to test best fit of the data. Consideration was given to selection of data points to be considered for inclusion in the regression, and what order the regression was performed. Mathematical methods were applied in a mechanical engineering context linked with service-learning for an integrated analysis. Topics covered in this S-L project included: regression analysis and introduction to statistics and statistical inference.

Learning objectives met by the S-L project were for students to:

- Determine whether one variable (dependent variable) is a function of another variable (independent variable)
- Postulate linear relationships to test experimental data points from UML student surveys
- Selected five independent variables postulated to have an effect on dependent variables
- Conducted a linear regression for each set of data
- Calculated 95% confidence intervals in each data case
- Developed conclusions and produce a report expressing what was done, why this was done, and how conclusions were reached

Service objectives met by the S-L project:

- Provided beginning analyses of S-L data from before SLICE

Mechanical Engineering Lab II, 22.403, Fall 2005

Faculty: Peter Avitabile

Partner Organization: Local Playgrounds

Partnership Description: Students in this course developed methods to test local playground surface hardness for safety. Course content focused on digital data acquisition systems used on mechanical engineering equipment. Students designed measurement systems composed of various transducers, their associated signal conditioners and digital data acquisition and recording devices. Statistical methods were emphasized and service-learning projects and experiments required students to provide calibration and to select appropriate sampling rates and test durations. Systems under test

ranged from simple multisensor laboratory apparatus to actual operating mechanical systems.

Project Description: Students worked in the ME Lab to assess playground safety. Testing and measurements of replication playground systems were conducted. Concerns regarding liability in terms of student level reporting and ethics of how to best communicate safety issues were discussed at a recent ME presentation. SLICE administration and the College of Engineering, plan to further explore such challenges of S-L scholarship.

Capstone 22.423, Spring 2006

Faculty: **John Duffy**

Partner Organizations: **Village Empowerment Peru Project, Kenya Village, and Assistive Technology Page-Turner for one Individual with Disabilities**

Partnership Description: Within this capstone course, four separate student projects emerged in partnership with the Village Empowerment Peru Project, a village in Kenya and Assistive Technology for one Individual with Disabilities. Two groups of students worked on two different project designs for the Village Empowerment Peru Project, a motorcycle ambulance and lanterns/ headlamps. One student worked on a solar-based design project for a chicken farm located in a village in Kenya. While a fourth student worked on a partnership project focused upon special needs of an individual child with disabilities.

Project Descriptions: The Motorcycle Ambulance Design for Peruvian remote villages was developed and the design idea discussed with remote health clinics in Peru during June 2006. The idea of the ambulance was to provide a low-cost means of transporting patients over narrow roads in the Andes using existing motorcycles in at least some of the medical clinics in remote villages. A follow on project is needed to be build and test a prototype.

A page-turner device was needed for a child with disabilities, and a prototype was built. The project was suggested by the assistive technology program in the electrical engineering department as a follow on to a previous project by an EE student. The mechanical part of the prototype appeared to work well, but a control system is needed.

A student from Kenya developed several solar designs for heating chicken houses and pumping water from wells as well as for providing energy to a residence for a chicken farm in Kenya, which resulted in a report and helpful recommendations. The designs are in the process of being implemented in Kenya.

Learning objectives met the S-L projects include:

- Apply the principles learned in other courses in the curriculum to the design of a mechanical system

- Develop performance criteria of a mechanism or system to meet the needs of a community partner
- Write a proposal to design the system or mechanism with tasks, deliverables, schedule of performance, and labor estimates
- Design the system or mechanism to meet the performance criteria
- If applicable, manufacture a prototype
- If applicable, test the prototype and evaluate the extent to which the device or system meets the performance criteria
- Evaluate the economic, safety, reliability, and/or social impact of the device or system design
- Write a logical and concise report on the design process and results
- Make a presentation to stakeholders about the design criteria, system, and results.

Capstone 22.423, Spring 2006

Faculty: **Sammy Shina**

Partner Organizations: Woods Hole Oceanographic Institute (WHOI), and FIRST Competition at Whitinsville Christian High School

Partnership Description: UMASS Lowell S-L students divided into two groups or teams to interact with partner organizations listed above. *WHOI is a non-profit organization specializing in ocean research, engineering and education located in Woods Hole, MA on the southwest corner of Cape Cod. WHOI's senior engineer, Jim Valdes, described an independent remote water sampling machine called "Argo" in need of redesign. He met with the UML team during the semester and reviewed their final results. One of the graduating UML students was hired full-time by WHOI.*

Project Description: SOLO Gear Case Load Cell for the Woods Hole Oceanographic Institute. Mechanical engineering capstone students were asked to design a tester mechanism for a high torque motor and gear case used in the Woods Hole Oceanographic Institute (WHOI) Argo Program. The program consists of a global array of 3000 free-drifting profiling floats that measure the salinity of the upper 2000 meters of ocean, allowing for continuous monitoring of temperature salinity and velocity of the upper ocean. The floats employ a high torque motor and gear box to maintain depth, by using a bladder that is inflated or deflated accordingly, by mechanical motion. The load cell is designed to simulate a load on the gear case motors similar to that which the motors will see in the ocean. The load cell and test apparatus designed by the students will ensure the proper operation of the floats in the ocean for the designed- in period.

Learning objectives met by the S-L project:

- Investigate the environment and the use of their project in helping to monitor the oceans to insure proper care of the environment for the future.
- Encourage technical communication skills by having the students produce a final report and presentations to other students in class using Microsoft office tools

- Experience working in close interaction and communications with professional engineers from WHOI, as well as with their advisor and laboratory managers at UML.
- Learn more about teamwork, project management and delivering a complex project on time and within budget
- Practice engineering and design ethical standards in taking data, analysis and performing their duties as prescribed
- Learn about safety in making their machines work through several days without supervision, insuring their own as well as the laboratory safety and proper procedures to take
- Explore the multi-disciplinary issues of motors and gears, some of which are mechanical as well as electrical and the use of software for data logging and analysis.
- Research and become familiar with the relevant codes used by industry in the design and manufacture of high technology and aquatic products, as well as safety and environmental codes.

Community objectives met by the project:

- A completed load cell and operating procedures for the motor gear case test, including connections to the WHOI computers and data logging programs.
- Summary of sample tests performed by the students and their data analysis was also included
- Help with global research into ocean temperature salinity and ocean current.

Partnership Description: This S-L partnership represents a collaboration between UML, the FIRST Competition and Whitinsville Christian High School since 2001. The FIRST Robot program with high schoolers linked with UML S-L students in which students acted as ambassadors to the local high school to work with high schoolers around robotics designs. Students performed independent design work and participated in team efforts to develop conceptual designs from functional requirements. Students performed design analysis and synthesis, modeling, fabrication, testing, cost estimating, and documented the essential elements of the system design.

*Project Description: **For Inspiration and Recognition of Science and Technology (FIRST) Robotic Competition:*** To design, manufacture and provide support for a working robot, which was then entered into the FIRST competition. FIRST is a nationwide robotic competition for high school students interested in the mathematics and science. The UML team of 3 students worked with students from the Whitinsville Christian High School throughout the entirety of the project for a total of 20 people involved. The robot was completed on time and within budget.

Learning objectives met by the S-L project:

- Exercise technical communication skills by having the UML students produce a final report and presentations to other students in class using Microsoft office tools
- Interact and communicate with high school students, their mentors, as well as with their advisor and laboratory and machine shop managers at UML.

- Learn about teamwork, working with younger students, project management and delivering a complex project on time and within budget
- Apply engineering and design ethical standards in design, taking data, analysis and performing their duties as prescribed
- Utilize safety in making their robot work very safe, as well as making sure that the high school students worked in safe environment when assembling or operating the robot.
- Research multi-disciplinary issues of motors and gears, controllers, computers and software, as well as explaining these issues to the high school students.
- Become familiar with codes used by industry in the design and manufacture of high technology and robotic products, as well as safety and environmental codes.

Community objectives met by the project:

- Advancement and interest of high school students in Math, Science and Engineering careers and topics.
- A completed and operating Robot was delivered to the high school student to train for operating the robot in competition. The robot design met all requirements of the high school design team and the robot competition rules in weight, power and steering.

The project was closely linked with the high school students, who were involved in the conceptual design of the robot, as well as operation the robot in competition. The high school students were motivated into careers of math, science and engineering. There were a good percentage of women represented on the high school project team.

Positive results for community:

The Whitinsville high school team and their mentors were extremely satisfied with the results of the robot and their performance in the competition.

Design Machine Elements 22.425, Fall 2005

Faculty: **Chris Niezrecki**

Partner Organizations: ***Lowell National Historical Park (LNHP), Tsongas Industrial History Center, Village Empowerment Peru Project, and Assistive Technology Project***

Partnership Description: The Lowell National Historical Park recently asked the engineering college's help canal trash cleanup and canal lock automation. The Tsongas History Center asked for resign of Googoplex to prevent fatigue failures when used by children touring the Center. One particular village in Peru requested a water system, and a tower design was needed. And a generic design for the knee joint of a low-cost prosthetic leg was needed.

Project Description: Two teams of students (three in each team) developed a ***Canal Lock Automation Project*** for the LNHP. The intent of the *Canal Lock Automation* was to design a mechanism to perform the task of opening and closing automatically an upstream water gate to allow boats to travel through at two different water levels. The upstream gates that allow boats to pass from one level of water to another in the Lowell Canal currently open and close manually. This process requires an operator to remain by the gate to perform the manual task of opening and closing the gate. The design teams

were given the challenge of designing a mechanism that automated the process so that a driver of a boat could push a button on a keypad. The mechanism would control unique parts of the Butterfly Wicket gateway. The students' report focused upon an analysis of the forces acting upon the gate. A design recommendation for an automated mechanism to open and close the gate was developed. Appropriate materials were selected for design elements. A stress and fatigue analysis was also performed for the automated gate design.

One team of three students developed a *Clean the Lowell Locks Project*. To clean the Lowell Canal locks, students proposed a design with a radio controlled floating device that has a collecting container that essentially skims the top of the water. Analysis of yielding failure and fatigue failure were conducted on the design joints. Though many assumptions were made, the students concluded that their proposed design was calculated to withstand the required loading and would hold up in fatigue.

One team of four students developed an *Analysis of Googoplex Blocks* project for the Tsongas Industrial History Center. The purpose of this analysis was to provide an evaluation of stress and fatigue characteristics of a googolplex construction toy. The problem presented by the center was a recurring failure in certain parts contained in the construction toy modeling set. Students conducted an analysis of first cycle stress levels based on displacements and material properties to address the failure problem and provided suggestions to extend the useful life of the toy parts.

Water Tank Support System for the School in Raypa. Three students tackled this project in order to design a safe structure to locate a water tank near the perimeter of the school in Raypa, Peru. Due to the lack of running water, a design for a water supply storage tank system was analyzed to allow running water to be accessible to a school located in Peru. Raypa is a remote Andean village in which running water is only accessible in the morning. A storage tank would allow running water to be available throughout the day to the school. Two different options were considered to investigate which would be a more viable structure. The tower was analyzed for static loads and recommendations for maintenance and prevention were shared in a final report to ensure a long useful life. A tower was designed with the objective being to use less metal than current towers in the region. The tower was welded in Huarmey and transported in January 2006 to the school in Raypa and constructed there by other UML and Peruvian students.

Three students also worked on a *Failure Analysis of a Prosthetic Knee*. A single axle knee joint for an economical prosthetic leg was the subject for a static and dynamically loaded failure analysis. A prosthetic leg is a complicated mechanical machine of various components. From prior research performed by the capstone student group that originally designed the leg, the bracket for the knee joint was assessed as the component most susceptible to failure. Since a failure of the prosthetic leg could result in bodily harm to a human, the leg was created based on a safety factor of 4 incorporated into the design.

Learning objectives met by the S-L project were for students to:

- Experience the design process, including working directly with a community partners
- Use the principles of mechanics and commonly used failure theories to design and analyze machine elements subjected to static and dynamic (fatigue) loading conditions.
- Study elements including power screws, bolts, springs, bearings, gears, lubrication, shafts, brakes, clutches, and belts.
- Perform a stress analysis or fatigue analysis that integrated recommendations
- Write brief technical reports and incorporate drawings

Community objectives met by the S-L project:

- Individual partners derived benefit through appropriate mechanical designs tailored to specific needs
- The LNHP project produced reports that continue to serve as potential mechanical designs to address this ongoing community need.

Analysis of Thermo/Fluid Processes 22.441, Spring 2006 Faculty: Majid Charmchi

Partner Organizations: Cambodian Mutual Assistance Association (CMAA) in association with the Architectural Heritage Foundation (AHF), and the Lowell National Historical Park (LNHP)

Partnership Description: The goal of this partnership was to assist two community organizations in which students worked in two different groups. One group focused on specific renovation objectives of the non-profit community building owned by the Cambodian Mutual Assistance Association (CMAA) by estimating dollar savings of utilizing air-to-air heat exchangers, sometimes called heat recovery ventilators (HRV). The Architectural Heritage Foundation (AHF), a non-profit developer, is assisting the CMAA in re-development plans with architectural programming. The partnership is working to address the buildings most immediate needs and plan for its renovation into housing and commercial space for locally owned businesses and community services. AHF provided a scope of engineering services to explore and evaluate. The second group of students worked on hypothetical data.

Project Description: Building codes typically require a 15 cfm fresh air intake for every occupant of a commercial building. CO₂ detectors can also be used to check for stale air and to control the makeup air rate. The energy consumed in heating and air conditioning this make-up air can be quite high. But a HRV can recover up to 80% of the heat or cooling energy. The contribution of the students involved in the project was to (a) measure the appropriate temperatures and air flow rates in a small HRV that was available in a UML lab; (b) extrapolate the performance of this particular HRV to a larger set of these in the CMAA building with planned renovations with estimated numbers of occupants; and (c) to estimate heating and cooling energy that would be saved in a typical year in Lowell (assumptions were made about the heating/ air condition equipment, and weather records available on the web for typical weather conditions), and (d) translate

those energy savings to dollar savings. HRV and related costs were estimated such as payback period, discounted payback, rate of return on investment, and life cycle savings. Students tested the heat exchanger system, collected the data, and reported on recommendations in terms of heat transfer rates for the A/C exhaust and thermal inefficiencies.

Learning objectives met by the S-L project were for students to:

- Experience the design process, including working directly with a community partners
- Convective heat transfer measurement
- Flow rate measurement
- Heat exchanger analysis and design
- Heat exchanger effectiveness
- Heat exchanges based on hypothetical data as well as real data
- Write technical reports and incorporate analyses

Community objectives met by the S-L project:

Community partners derived benefit through mechanical design analysis tailored to their specific need.

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set of these in the CMAA building with planned renovations with estimated numbers of occupants; and (c) to estimate heating and cooling energy that would be saved in a typical year in Lowell (assumptions were made about the heating/ air condition equipment, and weather records available on the web for typical weather conditions), and (d) translate those energy savings to dollar savings. HRV and related costs were estimated such as payback period, discounted payback, rate of return on investment, and life cycle savings. Students tested the heat exchanger system, collected the data, and reported on recommendations in terms of heat transfer rates for the A/C exhaust and thermal inefficiencies.

Learning objectives met by the S-L project were for students to:

- Experience the design process, including working directly with a community partners
- Convective heat transfer measurement
- Flow rate measurement
- Heat exchanger effectiveness
- Heat exchanger analysis and design
- Thermodynamic analysis of: gas power cycles, steam and combined cycles, and refrigeration cycles; mixtures of ideal gases
- Heat exchanges based on hypothetical data as well as real data
- Students tested the data and reported on recommendations in terms of heat exchanges for the A/C exhaust and thermal inefficiencies.
- Flow of a compressible fluid through a variable area
- Mach number, choking conditions, and normal shock.
- Write technical reports and incorporate analyses

Community objectives met by the S-L project:

- Community partners derived benefit through mechanical design analysis tailored to their specific need.

Design Theory and Constraints 22.473, Fall 2005 Faculty: Sammy Shina

Partner Organization: **Plastics Department Outreach Program**

Partnership Description: The Plastic Engineering Department was interested in the application of statistical methods for improving quality and reducing cost for plastic injection molded parts. Ice-scrappers are manufactured in the plastics engineering molding lab during demonstrations for visitors and distributed as giveaways to promote the application of STEM education. A collaborative effort was made between the mechanical and plastics faculty with the goal of manufacturing plastic parts of higher quality and lower cost using statistical techniques.

Project Description: **Optimization of Plastic Injection Molding Design and Manufacturing.** Four students in the Design Theory and Constraints (Mech. Eng.) course used the techniques of Design of Experiments (DoE) to improve the design and manufacture of plastic injection molded parts for higher quality and tighter tolerances for the Plastics department outreach program. Concepts of world-class design and

manufacturing of modern products, including the issues of Design for Quality (DFQ), cost and the customer were studied. Tools and techniques studied included Total Quality Management (TQM), statistical process control, process capability studies, six sigma quality, design efficiency ratings, design for cost, design of experiments, Analysis of Variance (ANOVA) of the mean and signal-to-noise ratio, and quality function deployment. Industrial case studies were used and student project work was required.

Learning objectives met by the S-L project:

- Practice technical communication skills by having the students produce a final report and presentations to other students in class using Microsoft office tools (Word, Excel, PowerPoint, Project).
- Opportunity for professional teamwork, working with other students from a different discipline (plastics), project management and using statistical techniques for improving quality and cost for design and manufacturing.
- Apply engineering and design ethical standards in design, taking data, analysis and performing their duties as prescribed
- Develop and exercise safe practices in making modern plastic injection molding machines work at optimum safety.
- Learn about the multi-disciplinary issues of plastics injection molding, as well as plastics material properties and cost analysis
- Explore codes used by industry in the design and manufacture of high technology and plastics products, as well as safety and environmental codes.

Community objectives met by the S-L project:

- A plan for designing and conducting a set of experiments to improve the quality and lower the cost of plastic injection molding parts, as well as the software needed to analyze them
- Assist in the advancement and interest of high school students, parents and other outside groups in Math, Science and Engineering careers and topics.

Elective/ Graduate Mechanical Engineering Courses

Energy Design Workshop 22.504 Spring 2006

Faculty: **John Duffy**

Partner Organization: **Greater Lowell Technical High School (GLTHS)**

Partnership Description: Students partnered with Environmental Science teachers at the Greater Lowell Technical High School (GLTHS) located in Tyngsboro and serves primarily Lowell high school youth (which represents a very diverse population base). GLTHS serves approximately 2100 students and was interested in conducting a feasibility study for solar photovoltaic systems, but desired to first prove that it would be a practical investment for the school both economically and educationally. GLTHS partnered with the U Mass Lowell Graduate Engineering Program's Energy Engineering Workshop course in pursuing the Large Onsite Renewables Initiative (LORI) grant available from the Massachusetts Technology Collaborative (MTC). A preliminary photovoltaic analysis was conducted that was geared toward maximizing incentives

eligible for through the LORI grant. A preliminary design proposal was generated based on recommendations, site, structure, and cost.

Project Description: Feasibility Study Proposal for Photovoltaic Energy System for Greater Lowell Technical High School GLTHS. This study included: (1) Site analysis; (2) Energy analysis; (3) Hardware analysis; (4) Cost analysis; and (5) Additional Recommendations.

The most attractive system to the school committee was the 28kW awning photovoltaic system; it is a decent sized system for the school, and the total energy contribution would increase as the energy efficiency of the building improves. A comprehensive summary of all recommendations made for the school and committee were provided by the UML students.

The school committee was so impressed with the study and report that they are considering funding aspects of the study recommendations. The report was also used as the basis for funding requests for an MTC LORI grant.

Solar Fundamentals 22.521, Fall 2005

Faculty: **John Duffy**

Partner Organizations: Village Empowerment Project, Peru; and Greater Lowell Regional Technical High School (GLTHS)

Partnership Description: This was a service-learning project in which academic goals were met along with real community needs. The overall goal of each of these S-L projects was to provide students with opportunities to apply theory and tools of solar engineering to an actual system and an opportunity to help communities, local and remote. UMASS Lowell students have since 1997 been working with residents of small remote villages in the Andes Mountains of Peru. Background information on the project is available at <http://energy.caeds.eng.uml.edu/Peru/index.shtm>. Students have also been working with Greater Lowell Regional Technical High School (GLTHS)

Project Description: Students were presented with a choice of two projects: (a) measured irradiation data analysis from Peru and (b) optimal slope, azimuth, and spacing for solar collectors on a flat roof at the nearby Greater Lowell Regional Technical High School

For the Village Empowerment Project based in Peru, students were provided with some hourly data from a data logger in the clinic in the town of Malvas, 3100 m elevation, 9.9170° S, 77.6830° W. Additional data from Raypa, 1400 m elev. 9.6500° S, 77.9170° W and some data from Cochapeti (9.9830° S, 77.6500° W, 3400 m) were also made available to students. The sites are in the same time zone as Lowell. It was suggested to utilize irradiation data from three sites to help design new solar systems in these areas. Data on photovoltaic array output and vaccine refrigerator energy use measurements were also provided in order to examine the data more closely to make sure it is

reasonable and useable for future work. Previously, no one had systematically reviewed and analyzed the data carefully. Good field data is hard to come by.

Technical objectives and tasks for the Peru Village Empowerment Project included:

- (a) Screen the measurements of irradiation, temperature, PV output, and vaccine fridge energy use. Sometimes sensors get dirty, have calibrations drift off, get disconnected, and then give inaccurate data. Screen all the data for obvious problems. Identify: missing data, suspected corrupted data. For irradiation data students were asked to compare:
 - (b) With the irradiation data, estimate if there is any shading from nearby mountains or trees or buildings. Discuss why it would be important to identify shading if this data was used to predict performance in other similar areas.
 - (c) Compare irradiation estimates with the hourly data to at least five estimates for each town based on monthly average irradiation data from representative towns in our database (<http://energy.caeds.eng.uml.edu/fpdb/irrdatab.asp>) or other appropriate available databases.
 - (d) Tabulate the PV system energy generated by month as well as the energy consumed by the vaccine refrigerators.
 - (e) The town of Muchipampa has requested a water pumping system. It is close to the town of Quillapampa, which has coordinates of 9.85 S and 78.02 W and has an elevation of approximately 1000 m. Estimate the twelve monthly average horizontal global irradiation values based on analysis of our own data from the three other towns and other available data for the town of Quillapampa.

*Project Description: **Optimal Spacing and Tilt (slope) and Azimuth Collectors for a Feasibility Study for Greater Lowell Regional Technical High School.*** The goal of this project was to estimate the optimal slope and azimuth and spacing to fit as many collectors as possible in a given roof area in order to obtain maximum incident irradiation. Student objectives for this project included: experimenting with the usage of solar irradiation by estimating angular positions for collector plates such as optimal slope, azimuth angle, and optimal spacing between collectors. Teams of two students generated final reports with results, conclusions and recommendations for each site. Students reported on their methodology and how they met the objectives outlined above.

*Project Description: **Design of Water Pumping Systems without Batteries for Villages in the Peruvian Andes.*** A team at UMass Lowell has been traveling to Peru for the past seven years in order to assist the living conditions of residents in remote villages. These villagers live without clean water and electricity. Therefore, one of the group tasks has been to design and install solar powered water delivery systems. Unfortunately, some of these systems have been failing due to different reasons. Designs of improvement are now being considered. The objective of this project was to analyze the current design of one pump system and look at possible changes, such as connecting the pump directly to the PV modules without the assistance of storage batteries. Students also considered how realistic it would be to run a system without batteries.

Specific project tasks included: Estimation of the monthly average irradiation on the PV modules for each month of one year; Measures of Isc and Voc of two Evergreen 50 W modules; Comparison of design to manufacturer specifications; Calculation of the amount of energy to pump 500 liters of water to a height of 25 meters; Redesign of the system to eliminate the use of batteries; Development of a mathematical model of startup; Sketch a wiring diagram of the system; Specification of the wire gage to limit power loss to 3%; Performance of an hourly simulation with estimated hourly solar irradiation and ambient temperature for the worst month; Track loss of load; and Discussion of the advantages and disadvantages of the system with and without batteries.

Solar Systems 22.527, Spring 2006

Faculty: **John Duffy**

Partner Organizations: **United Teen Empowerment Center (UTEC), Lowell, MA**

Partnership Description: UML students worked with the local United Teen Empowerment Center (UTEC) to develop green building and solar designs for their recently acquired new center location. UTEC recently purchased the former St. Paul's United Methodist Church to serve as their new permanent center. UTEC was and continues to actively seek volunteers with experience in designing and renovating a building to assess structural, electrical and general construction. UTEC continues its campaign to transform the former St. Paul's United Methodist Church to provide a safe haven for local youth development and grass roots organizing.

Project Description: **Green building and solar designs for the United Teen Empowerment Center (UTEC).** The overall goal of this project was to provide students with an opportunity to help communities, local and remote. This represented a S-L project in which academic goals were met along with real community needs. Students investigated possibilities of alternative energy sources for UTEC's recently purchased building and proposed additions. Students analyzed existing structures and proposed structure's compositions and assessed overall heat loss coefficients. Given the positioning of the building and associated construction compositions, students developed detailed recommendations that included: super-insulation, energy efficient lighting, installation of shading during summer months, use of a Photovoltaic (PV) panel system to be installed on a south facing roof of the existing building, double glazed insulated window replacements, installation of ceiling fans to cool the building, and installation of air to air heat exchangers to be installed in both buildings to provide ample air circulation.

Vision of and mission of the Solar MiniProject for UTEC was described: As teens come to the UTEC community and become more self reliant, the UTEC building they gather in will also reflect self sufficiency in its usage of energy. The mission was described as a project developed "by teens, for teens" safe haven to promote science and technology for youth development. Students worked to suggest measures that improve the passive solar performance of the proposed UTEC design while improving the environment within the building. Students concluded that reducing the cost of energy is possible with the integration of passive solar systems.

Learning objectives met by the S-L project:

- Developing skills in meeting technical objectives of green building design and photovoltaic system design
- Evaluating the potential sociological impact of solar technology on the community
- Estimate monthly average irradiation and extrapolate estimates to the community location
- Measurements of solar irradiation
- Development of designs based on criteria gathered
- Specify charge controllers and sketch wiring diagrams of the systems
- Perform an hourly simulation of the systems with estimated hourly solar irradiation and ambient temperature for one year
- Track loss of load
- Suggest innovative energy systems
- Final report that included methodology, results, conclusions and recommendations.

Community objectives met by the S-L project:

- Potential plans and suggestions for community consideration regarding integration of solar designs during transformation of recently acquired building.
- An application for support for photovoltaic arrays for the new and renovated building was made to the Massachusetts Technology Collaborative with the assistance of the students and faculty as a follow up in the fall of 2007.

Non-Engineering Courses (Required for Some Engineering Programs)

Engineering Ethics 45.334, Fall 2005 and Spring 2006 Faculty: Gene Mellican

Partner Organizations: **Village Empowerment Project, Peru**

Project Description: In the fall 2005 course, students examined opportunities for specific application of nanotechnology that has potential to meet an existing or material need of the Peruvian mountain villagers in contact with the UML Peru team or people living in similar conditions in other developing countries. In the spring of 2006, students investigated potential impacts and results (both positive and negative) for the village community that could follow from application of a nano-based product or process, including consideration of potential environmental, health or safety risks, projected timeframe for development, and cost effectiveness of production process.

Appendix B Student Survey (Post 2006)

SURVEY (post) on Service-Learning, UML College of Engineering

Instructor's name: _____

Student ID (ISIS No.):

Instructions:
For each question, make a solid mark
that fills the oval completely.

I like this: Not like this:

Course #

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H. Have you ever been involved in community service activities before this course? (check all that apply)

- No
- Yes, during high school
- Yes, during college

I. How many credit-hours of courses are you taking this semester?

- | | |
|-------------------------|-------------------------|
| | |
| <input type="radio"/> 0 | <input type="radio"/> 0 |
| <input type="radio"/> 1 | <input type="radio"/> 1 |
| <input type="radio"/> 2 | <input type="radio"/> 2 |
| | <input type="radio"/> 3 |
| | <input type="radio"/> 4 |
| | <input type="radio"/> 5 |
| | <input type="radio"/> 6 |
| | <input type="radio"/> 7 |
| | <input type="radio"/> 8 |
| | <input type="radio"/> 9 |

J. What is your current academic status?

- Freshman
- Sophomore
- Junior
- Senior
- Graduate

K. Please rank your five (and only five) most important career values (1 = highest, 0 = those you don't choose):

- 0 1 2 3 4 5 *Challenge: Learning new skills or information, self-development*
- 0 1 2 3 4 5 *Creativity: Doing things in a new way or inventing things*
- 0 1 2 3 4 5 *Helping: Doing things for others, building a better world*
- 0 1 2 3 4 5 *Income: Making a high salary*
- 0 1 2 3 4 5 *Independence: Being our own boss, deciding how and when to do your work*
- 0 1 2 3 4 5 *Outdoors: Working outside, in different types of weather*
- 0 1 2 3 4 5 *Physical: Being physically active at work, or being physically inactive*
- 0 1 2 3 4 5 *Prestige: Doing work that is seen as important, and for which people respect you*
- 0 1 2 3 4 5 *Public: Providing information to, and interacting with the public*
- 0 1 2 3 4 5 *Security: Having stable employment and income, not worrying about lay-offs*
- 0 1 2 3 4 5 *Variety: Doing many different activities, not doing the same things all the time*
- 0 1 2 3 4 5 *Team: Being cooperative, getting to know co-workers*

Please respond based on your honest reaction to each item. Please choose the answer that makes sense to YOU; not what you think others would say.

[1= Strongly Disagree, 5=Neutral, 9=Strongly Agree]

1. Service and academic coursework should be integrated. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
2. Engineers should use their skills to solve social problems. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
3. I feel that social problems are not my concern. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
4. People who receive social services largely have only themselves to blame for needing services. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
5. Social problems are more difficult to solve than I used to think. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
6. The problems of unemployment and poverty are largely the fault of society rather than of individuals. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
7. I feel that I can have an impact on solving problems that face my local community. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
8. I feel that I can have an impact on solving problems that face under-served communities internationally. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
9. It is important to me personally to influence the political structure. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
10. It is important to me personally to have a career that involves helping people. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
11. I feel uncomfortable working with people who are different from me in such things as race, wealth, and life experiences. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨
12. I have developed a close personal relationship with at least one faculty member at this institution. ① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨

“Service-learning” is a hands-on learning approach in which students achieve academic objectives in a credit-bearing course by meeting real community needs.

13. Was being able to take classes with service-learning one of the reasons you chose UMass Lowell?

- Yes
- No

14. Since enrolling at UMass Lowell, how many classes have you taken where service-learning opportunities were part of the class?

- | | |
|-------------------------|-------------------------|
| — | — |
| <input type="radio"/> 0 | <input type="radio"/> 0 |
| <input type="radio"/> 1 | <input type="radio"/> 1 |
| <input type="radio"/> 2 | <input type="radio"/> 2 |
| <input type="radio"/> 3 | <input type="radio"/> 3 |
| <input type="radio"/> 4 | <input type="radio"/> 4 |
| | <input type="radio"/> 5 |
| | <input type="radio"/> 6 |
| | <input type="radio"/> 7 |
| | <input type="radio"/> 8 |
| | <input type="radio"/> 9 |

15. To what extent has/have your service-learning project(s) at UML had an impact on the following:

[1= Strong Negative Impact, 5=Neutral, 9=Strong Positive Impact]

- | | | | | | | | | | |
|--|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|
| a. Increased my belief that I can make a difference in the community | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| b. Increased my interest in learning | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| c. Increased my commitment to being involved in community issues as an engineer | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| d. Improved my ability to write and speak credibly about community issues as an engineer | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| e. Improved my ability to find information about an issue or a problem in the community | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| f. Taught me how to evaluate many different types of information for usefulness and accuracy | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| g. Taught me decision-making skills | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| h. Increased my leadership skills | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| j. Increased my understanding of the value of teamwork in addressing community issues | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |
| k. Increased my ability to plan and carry out a project for the community | <input type="radio"/> 1 | <input type="radio"/> 2 | <input type="radio"/> 3 | <input type="radio"/> 4 | <input type="radio"/> 5 | <input type="radio"/> 6 | <input type="radio"/> 7 | <input type="radio"/> 8 | <input type="radio"/> 9 |

16. This semester did you participate in a class project that addressed a real community issue or problem through service-learning?
- Yes (go to 18a)
- No (go to question 19)

- 16 a) If yes, approximately how many hours did you spend working on this project?
- | | |
|-------------------------|-------------------------|
| _____ | _____ |
| <input type="radio"/> 0 | <input type="radio"/> 0 |
| <input type="radio"/> 1 | <input type="radio"/> 1 |
| <input type="radio"/> 2 | <input type="radio"/> 2 |
| <input type="radio"/> 3 | <input type="radio"/> 3 |
| <input type="radio"/> 4 | <input type="radio"/> 4 |
| | <input type="radio"/> 5 |
| | <input type="radio"/> 6 |
| | <input type="radio"/> 7 |
| | <input type="radio"/> 8 |
| | <input type="radio"/> 9 |

- 16 b). If yes, was participation in this project required or optional?
- Required
- Optional
- 16 c) If yes, please check which best describes your role in the project:
- I was in a leadership role
- I was very involved as a team member
- I was a moderately involved team member
- I carried out the project on my own
- Other

17. Please respond based on your honest reaction to each item. Please choose the answer that makes sense to YOU; not what you think others would say.
 [1= Strongly Disagree, 5=Neutral, 9=Strongly Agree]

- a. The amount of effort I put into the service-learning project was greater than what I would have put in for an equivalent class project not involving service. 1 2 3 4 5 6 7 8 9
- b. In the service project, I learned how engineers apply the concepts I learned in class to real-life problems. 1 2 3 4 5 6 7 8 9
- c. In the service project, I learned how to work with others effectively. 1 2 3 4 5 6 7 8 9
- d. The service project(s) made it more likely that I would continue in engineering. 1 2 3 4 5 6 7 8 9

18. What formal mechanisms did you use in your service-learning class to assess what you learned through your service-learning project? (*Check all that apply*)

- | | |
|---|---|
| <input type="radio"/> Discussion | <input type="radio"/> Written assignments other than a report |
| <input type="radio"/> Making a presentation | <input type="radio"/> None |
| <input type="radio"/> Keeping a journal/log | <input type="radio"/> Other |
| <input type="radio"/> Written reports | |

19. Comments and suggestions:

Thank you!

For more information about service-learning, please contact
Linda Barrington, Phone: (978) 934-2827
E-mail: linda_barrington@uml.edu

