Service-Learning as an Educational Tool in an Introduction to Engineering Course

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Abstract

Service-learning is a form of instruction which uses community service activities as part of the medium for learning. There are two components: (a) service which actively engages the student in community service, and (b) focused-directed learning. Service learning enhances the engineering curriculum by linking engineering directly to improving society, which makes the profession more appealing and more diverse.

At Virginia Commonwealth University (VCU), service-learning has been incorporated into a section of the *Introduction to Engineering* course. Students are given an opportunity to participate in the service-learning (s-l) laboratory section. These students are teamed with local high school students. As a result of their participation in the course, the VCU students (a) gain a better understanding of the concepts presented in class through the process of having to teach/explain these concepts to a high school student, (b) learn about the concept of mentoring, (c) reflect on one's own values and feelings about community service, (d) realize the importance of community service and its incorporation in the field of engineering, and (e) achieve the goals set forth in the course syllabus. The high school students (a) gain exposure to college and the study of engineering, (b) learn more about engineering and the types of things engineers do, and (c) learn about electronics and the construction of a digital programmable mobile robot.

This paper describes service-learning and the *Introduction to Engineering* course and how the two are incorporated to enhance the educational experience of the VCU students and provide a service to the Richmond, Virginia community.

I. Introduction

As institutionalized service-learning has developed, there have been many different definitions of this pedagogical approach to teaching. Each definition has subtle differences that cater to each individual program. There is not one set definition that will satisfy everyone. Two definitions are listed below.

In the National and Community Service Trust Act of 1993 , service learning was defined as "... a method under which students or participants learn and develop through active participation in thoughtfully organized service that: is conducted in and meets the needs of a community and is coordinated with an elementary school, secondary school, institution of higher education, or community service program, and with the community; helps foster civic

responsibility; is integrated into and enhances the academic curriculum of the students or the educational components of the community service program in which the participants are enrolled; and includes structured times for the students and participants to reflect on the service experience.[1]"

The technical definition of Service Learning as an Instructional Method according to the *Code of Federal Regulations* is a methodology:

i. under which students learn and develop through active participation in thoughtfully organized service experiences that meet actual community needs and that are coordinated in collaboration with school and community;
ii. that is integrated into the students academic curriculum or provides structured time for a student to think, talk, or write about what the students did or saw during the actual service activity;
iii. that provides students with the opportunities to use newly acquired skills and knowledge in real-life situations in their own communities; and
iv. that enhances what is taught in school by extending student learning beyond the classroom and into the community and helps foster the development of a sense of caring for others.[2]

In the fall semesters of 1998 and 1999 at Virginia Commonwealth University (VCU) in the School of Engineering, a group of freshmen students in one section of the *Introduction to Engineering* course (ENGR 101) were offered an opportunity to participate in a service-learning project. ENGR 101 is a laboratory based required course for all engineering school freshmen in their first semester. The students build a digital programmable mobile robot in the laboratory and in class the students learn about the fundamental principles behind the operation of the robot.

Since this course is a required course, the students were given an opportunity to participate in the service-learning laboratory section if they so chose. It was explained to the students that those who chose the service-learning laboratory would be teamed with a high school students from local Richmond public high schools. They would perform the laboratory with a high school student and explain the concepts to them. In the first lecture the goals and concepts of service-learning were explained.

II. Service-learning

Community service and community programs are very important components of VCU. The university has exemplified its commitment to the community by establishing the Office of Community Programs (OCP) in the Office of the Provost. The mission of this office is to "facilitate a dynamic exchange between VCU and the community to enhance the quality of life for all who work, live, and study in the Richmond, Virginia metropolitan area. [3]" Service-learning at VCU is a course-based, credit-bearing educational experience in which students participate in an organized service activity that meets community-identified needs. Students reflect on their service activity in such a way as to increase their understanding and application of the course content and to enhance their sense of civic responsibility.

Typically a service learning course requires a minimum of fifteen hours of service with selected community-based organizations or schools. Faculty who teach service-learning courses have found that extending the boundaries of the classroom into the community benefits their students' learning in many ways. Students understand and synthesize the subject matter through a broader range of experiences and associations; gain an understanding and appreciation of the community and its people with diverse background and life situations; explore an area of study or a career option; critically reflect on their values and responsibilities as citizen; and gain a belief that through their actions they can make a difference [1,4,5].

In service-learning education, the students in the class provide a service to address community-identified needs of individuals, organization, schools, or entities in the community. The service experience elucidates the relevancy of the course content. The service opportunities seek to further the students civic education while providing skill development valuable for career preparation. By using diverse teaching methods, students are encouraged to think about what they have learned through the service experience and how these topics relate to the course content. The class activities are designed such that class members learn from each other as well as from the instructor. The course offers a method to assess the learning derived from the service and credit is given for the learning and its relation to the course, not for the service alone. Recipients of the students service are offered the opportunity to be involved in the assessment of the service.

In the Service-Learning Associates Program Faculty Handbook , the following distinctions are made between the learning objectives in the traditional course versus those in a service learning course.

	Traditional Course	Service-learning Course
Place	Classroom	Classroom, Community
Teachers	Professor	Professor, Supervisor, Clients
Preparation	Readings, Previous courses	Expanded Readings, Previous Courses, Personal Characteristics
Learning	Writing, Exams Cognitive Short Term	Writing, Exams Cognitive and Affective Short and Long Term
Evaluation	Professor	Professor, Supervisor, Self-Assessment

Table 1: Distinctions between a traditional course and a service learning course [1]

Traditional Course	Service Learning Course
Authoritarian	Shared Responsibility
Top Down	Bottom Up
Convergent Thinking	Divergent Thinking
Deductive	Inductive
Acceptance	Analysis, Critique
Linear	Nonlinear
Structured, Compartmentalized	Expansive, Integrative
Learning assessed at end of course	Learning can take place after course
Passive	Active

Table 2: Additional distinctions between a traditional and service-learning course [1]

Service-learning is a complement to classroom learning. It is a teaching tool that focuses on critical thinking and problem solving, values clarification, social and personal development, and civic and community responsibility. These are all goals that are valued in engineering education and thus service learning is another pedagogical approach that can that can be incorporated in the traditional engineering curriculum. *Introduction to Engineering* courses are a perfect place to implement this teaching tool.

III. Introduction to Engineering

Across the nation in engineering programs there are *Introduction to Engineering* courses. The primary goals of these courses are to provide freshmen with a taste of what engineering is and to cultivate their interest in the field. Often times, students who have decided to major in engineering do not really know what the discipline is all about. It takes a good *Introduction to Engineering* course to expose them to what engineering really is and to solidify their interest in the career. The goal of the *Introduction to Engineering* course at VCU is the give the students a broad exposure to engineering and give them enough theory to basically understand the general operation of the devices they are working with in the laboratory, in order to entice their interest in engineering without overwhelming them. The course covers a wide breadth of areas and gives the students the hands on laboratory experience to demonstrate the theory they are learning in class.

The *Introduction to Engineering* course at VCU is a four-credit-hour course that consists of three lecture hours and three laboratory hours each week. The course introduces the basic concepts and principles of engineering and provides the foundation needed to pursue a career in an engineering profession. These basic concepts, common to electrical, computer, and mechanical engineering, are motivated in the context of real applications. The course is a

laboratory-based course in which the students build a digital programmable robot (shown in figures 1 and 2) in the laboratory and learn about the concepts and laws that govern the electrical and mechanical operation of the robot. The students analyze, construct, and test the electromechanical system. The study of this system illustrates how complex systems may be decomposed into simpler modules. These modules incorporate elements from a broad range of areas within the discipline of electrical engineering.

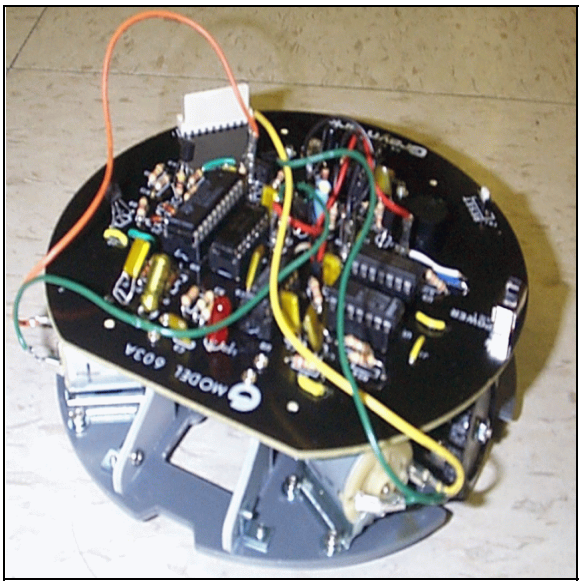

Figure 1 Completed robot

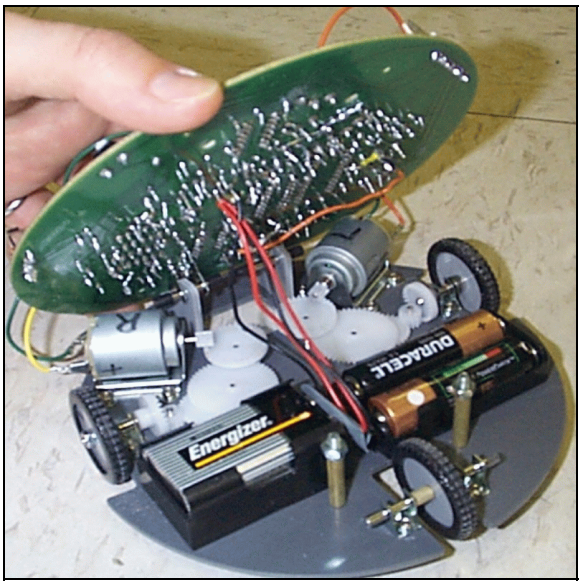

Figure 2 Completed robot

The laboratory exercises reinforce the concepts introduced in the lectures. These exercises consist of building, analyzing, testing, and debugging a series of subsystems that comprise the programmable mobile robot. The students are required to keep a laboratory notebook in which they keep a record detailing the theory, process, and results of each laboratory experiment. There are a total of fifteen laboratory experiments. Each week the lectures tie directly to what the students are doing in the laboratory. Table three presents the course syllabus.

Upon successful completion of the course the students are able to:

1. Decompose a complex system into simpler modules, and think logically about problems and the process of obtaining solutions.
2. Apply basic circuit laws to analyze simple circuits.
3. Use behavioral models of semiconductor devices, such as diodes and transistors in circuit analysis.
4. Understand the workings of various transducers such as speakers and motors.
5. Understand mechanical power and torque.
6. Understand Boolean expressions and implement them using logic gates such as AND, OR, NAND, and NOR gates.
7. Build Karnaugh maps and develop minimum Boolean expressions.
8. Appreciate the practicalities of getting things to work and understand why sometimes real systems behave differently from what they predicted based upon theory.

	Lecture	Laboratory
Week 1	Introduction; Systems and Subsystems; Voltage, Current, Resistance, and Power; Ohm's Law; Joule's Law	Lab Familiarization I ; Soldering
Week 2	Kirchoff Laws (KVL, KCL); Node Analysis	Lab Familiarization II; Sources and Meters; Resistive circuits
Week 3	Behavioral Models of Diodes: LED, Signal, and Zener	Diodes
Week 4	Behavioral Models of Transistors: BJT, NPN	LED Driver Circuit
Week 5	Capacitors; Exam 1	Voltage Regulator Circuit
Week 6	Binary Logic and Logic Gates	Clock Circuit
Week 7	Boolean Algebra and Karnaugh Maps	Speaker Driver Circuit
Week 8	Flip-Flops and Timing Diagrams	Robot Subsystems Check
Week 9	Data Registers, Counters	Reset Circuit
Week 10	RAM; Exam 2	Memory Load Sequencer Circuit
Week 11	Coils and Transformers; Newton's Laws	Counter and Memory Circuit
Week 12	D.C. Motors	Motor Driver Circuit
Week 13	Mechanical Power and Torque; Gears and Power Train	Robot Mechanical Assembly
Week 14	Guest Lecturer (Industrial Engineer)	Robot Subsystems Check
Week 15	Complex Systems and Engineering Issues; Ethics in Engineering	Final Robot Performance Test

Table 3: Course Syllabus

IV. Service-Learning in *Introduction to Engineering*

This first challenge to incorporating service-learning into the course was justifying why this should be done. All too often, engineering is misrepresented as a boring field where one is surrounded by the "Dilberts" of the world and the engineer has little contact with what is actually going on in the world outside of engineering. By incorporating service-learning into engineering courses, a link is established between engineering and improving society. This link gives an added appeal to the profession, which translates into diversifying the field. Industry has made it clear that they need engineers with a broader outlook, better team skills, a

strong ethical sense and a global awareness. Working with the community partners ensures real issues and thus practical experiences. It helps the students realize the broader impact of engineering and the ethical responsibilities engineers have to the larger community.

There have been several examples of successful programs where service-learning has been incorporated into science, mathematics, and engineering curricula. Examples of these programs include Duke University where students work in a rehabilitation hospital for chronically ill children; Copper Union University where engineers teach laboratories and tutor in a high school outreach program and visit elementary schools where they demonstrate technical projects for children; Purdue University where they have a center for Engineering Projects in Community Service (EPICS); WPI where sophomores and seniors work on project that the students select that benefit a community partner; University of South Alabama where freshmen mechanical engineering students complete a project and demonstrate it and explain its principles of operation to middle school students; Augsburg College where students in an upper level mathematics class analyze data for community partners such as Habitat for Humanity, the Minnesota AIDs program, and Citizens for a Better Environment; and University of Washington where students can take an Issues of Science on Society upper level chemistry class. Each of these programs has demonstrated how service-learning can be used in a technical curriculum to enrich the learning experience.

Using these programs as examples, the service-learning section of *Introduction to Engineering* was designed. In the fall semesters of 1998 and 1999 a section of the *Introduction to Engineering* course was set aside as a service-learning section. On the first day of class the goals of the course were reviewed and service-learning was explained. The expectations of the students were carefully laid out and the mechanics of the laboratory was explained.

It was explained to the students that high school students would be teamed up with them in the laboratory. During the laboratory, the VCU students would include their high school partners and allow them to participate in the construction, testing and analysis of the circuit for that week's laboratory experiment. The VCU students were required to explain everything that was going on in the experiment and answer whatever questions the high school students had. The high school students would receive the laboratory reading one week prior to actually performing the experiment, but that was the only instruction they would receive outside of the laboratory. A large part of the explanation and demonstration would fall on the shoulders of the VCU students.

The goals of the s-l section were classified into two categories; goals for the VCU students and the goals for the high school students. The goals for the VCU students were:

1. To gain a better understanding of the concepts presented in class through the process of having to teach/explain these concepts to a high school student,
2. To learn about the concept of mentoring,
3. To reflect on one's own values and feelings about community service,
4. To realize the importance of community service and how it can be incorporated into the field of engineering, and
5. To achieve the goals set forth in the ENGR 101 syllabus.

The goals for the high school students were:

1. To gain exposure to college and the study of engineering at college,
2. To learn more about engineering and the types of things engineers do, and
3. To learn about electronics and how to construct a digital programmable mobile robot.
4. To expose traditionally under-represented minority groups to the field of engineering

In the fall of 1998 when the first service-learning section was offered, the students were given the option to participate. Out of thirty students in the section, ten volunteered to participate in the service-learning section. Five students from Richmond Community High School were selected to participate in the laboratory. Of the five high school students, all were minority and three were female and two were male.

The demographics of the VCU class and laboratory sections in the fall of 1998 were as follows:

	Standard Lab Section	Service-learning Section	Total
Total	20	10	30
Male	17	4	21
Female	3	6	9
Minority	2	1	3

In the fall semester of 1999 there were 7 high school students participating in the laboratory. These students came from Richmond Community High School, the Governors School, and John F. Kennedy High School. Of the high school students, six were male and one female and four were minority.

The demographics of the VCU class and laboratory sections in the fall of 199 were as follows:

	Not Participating in Service-learning	Participating in Service-learning	Total
Total	6	12	18
Male	7	11	21
Female	1	1	2
Minority	4	4	8

Each week the students were given an opportunity to provide feedback in their laboratory notebook on the service-learning experience. In the fall of 1998 the overall experience was extremely positive for both the high school students and the VCU students. There were more

challenges in the fall of 1999 section. One high school student dropped out of the program because of lack of interest and personality conflict with his laboratory partners. A second high school student requested a change in partners because his VCU laboratory partners were having trouble explaining the concepts to him and the experiments would run pass the allotted laboratory meeting time.

At the end of the semester all participants were asked to write their comments on the experience and asked to provide any suggestions on improvements for the course. Based upon the student responses, I would consider the service-learning section of *Introduction to Engineering* a success. The students were very willing to give feedback about the course. Below are a few selected statements from the student evaluations collected mid-semester. One of the VCU students commented: "When building our robot we had to take a little extra time to help (student) understand what we were trying to do. This was not a nuisance at all. It actually made us have an even more thorough understanding of the concepts... This also cleared up any misconceptions I might have had... I was forced to get clearer 'picture' myself." One of the high school students commented: ' The Engineering VCU and (high school) partnership has greatly heightened my knowledge of a field that may soon become my career choice... My laboratory partners were definitely vital part of my experience. They made sure that I understood everything... I only hope that others should be as fortunate as I was to take part in such a partnership."

V. Commentary and Conclusion

Typically, when thinking of service-oriented professions, engineering might not come to mind. Typically, teaching, nursing, social work, etc. are considered service oriented professions. Numerous other professions provide a service to our community, including engineering, journalism, broadcasting, marketing, sales, etc. If there is a need or a desire presented by society, then industry will find a way to meet that need and most often will try to meet it for a price that will earn them a profit. When industry meets the needs of society voluntarily free of charge, then there is community service or volunteer work.

Often there is confusion about the difference between volunteer work and service-learning. Volunteer work is different from service-learning because it does not have curriculum associated learning with it. Volunteer work is typically performed simply for altruistic reasons. Service-learning however, is performed to reinforce concepts learned in the classroom.

Service-learning also differs from paid summer internships, cooperative education, and research. These are all forms of experiential learning. However, summer internships, cooperative education, and career-oriented research are not designed to meet the needs of the community free of charge. In fact these forms of experiential learning are designed to benefit the student and employing company. Experiential learning is a vital part of engineering curriculum and our students obtain valuable job training, work experience and industrial contacts through these irreplaceable experiences. Service-learning in no way takes the place of or devalues these other forms of experiential learning. In fact, the two forms of learning complement each other.

If the goal is to produce engineers who "... can demonstrate an ongoing awareness and understanding of critical issues in the world, nation, state and community and their interrelations" (VCU electrical engineering learning outcomes objective) or who have "an understanding of professional and ethical responsibility and have the broad education necessary to understand the impact of engineering solutions in a global and societal context" (ABET EC 2000 criterion [6]), then I propose that service-learning is simply one method by which one can ensure these desired learning outcomes are achieved.

As a professor of engineering, I teach our students how to solve problems using technology or by creating new technologies. I present them with problems, give them tools, teach them theories and say 'create a solution'. To help them understand better how to apply their knowledge, I present them with 'real world problems'. I can only hope, that in the future as my colleagues and I meet the needs of our students and community, that we not only solicit these real world problems from our industrial partners, but also from community partners. In any service-learning class the goal is not only to produce educated students but also to educate those who realize the impact of what they are learning on the community as a whole. The goal of a university is to produce educated citizens, not just educated people. Service-learning affords us the opportunity to educate the citizenry.

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