Teaching a Service Learning Introductory Engineering Course - Lessons Learned and Improvements Made

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Abstract - **This paper describes the format of an introductory engineering course that applies service learning teaching pedagogy. The semester-long service learning project consists of mentoring elementary and middle school students during an eight week long LEGO robotics competition that is annually held at Texas Tech University in Lubbock, Texas. The service learning section is currently being offered for the second time by the same instructor and this paper describes adjustments that were made resulting out of the experiences during the first year.**

Index Terms - Service Learning, Introduction to Engineering Course, Freshmen Engineering Course, LEGO robotics

INTRODUCTION

"Service learning is a pedagogy that links academic study and civic engagement through thoughtfully organized service that meets the needs of the community", [1]. Over the last years, service learning has been explored within the field of engineering. The most widely known service learning program in engineering is the EPICS program at Purdue University [2]. According to [3] these community service opportunities within engineering are particularly attractive to women. 70% of the participants reported that the service learning course positively affected their retention in engineering.

Texas Tech University (TTU) has an official Service Learning Program [1] in place which is hosted at its Teaching, Learning, and Technology Center (TLTC). It offers an annual Service Learning Fellowship Program and Service Learning Mentoring Program to which faculty can apply. Service Learning Fellows and Mentors meet monthly to listen to presentations, network, exchange ideas, promote service learning, and provide mutual support. Courses with service learning projects receive an official "S" dedication through an application process where the course description and the syllabus are reviewed by a Service Learning Advisory Council [1] consisting of faculty and staff from all TTU colleges. TTU has been recognized by the Carnegie Foundation for the Advancement of Teaching [4] for outstanding community service and partnerships and has been awarded a spot on the President's Higher Education Community Service Honor Roll [5] in 2008.

The author was awarded a Service Learning Fellowship for the academic year 2009/2010. She had previously started to organize an annual LEGO robotics competition in Lubbock for students in elementary and middle schools, Get Excited About Robotics (GEAR) [6] in Lubbock, which was funded through the Texas Workforce Development Grant Program from 2006 to 2008 [7]. As part of this grant a pipeline of engineering outreach activities for K-12 students was implemented and interleaved with paid mentoring opportunities for ECE undergraduate students, in order to increase retention rates among currently enrolled students. The continuous growth of the robotics competition and the success of teaming up ECE undergraduate students with teachers to coach the robotics participants, where the teacher is experienced in working with K-8 students while the undergraduate student is the technology expert, motivated the author to formally incorporate the LEGO robotics competition as a service learning project into a freshman level engineering course.

SERVICE LEARNING INTRODUCTION TO ENGINEERING COURSE IN 2010

ENGR 1315 Introduction to Engineering is a freshman level engineering course offered at the Whitacre College of Engineering at TTU and is open to all engineering majors. The course is mainly taken by engineering and pre-engineering freshmen during their first year at TTU. It provides an "introduction to the engineering profession, including the distinction between different majors, engineering problem solving, professionalism and ethics, and experiences in team design projects." [8]. The course fulfills the "Core Technology and Applied Science" requirement in the state of Texas [9].

The author decided that the GEAR competition would be a great occasion to expose students to a variety of tasks in the engineering field while building on skills that were appropriate for freshmen. The GEAR competition held at TTU annually kicks off in February during Engineering Week. Prior to kickoff, game board and game pieces have to be manufactured according to instructions provided by the GEAR board [6]. During the kickoff event, schools receive those game pieces and K-8 participants learn about the challenges and rules of the upcoming competition. The elementary and middle school teams then design their programmable robots from LEGO MINDSTORMS NXT

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[10] kits at the schools while being coached by their teachers and engineering students. After 5 weeks, they return to TTU for a trial run and the competition takes place middle of April, when teams compete against each other for awards. The author envisioned students enrolled in ENGR 1315 to be involved in all aspects of the competition ranging from wood and metal work to building the game pieces, mentoring participants at local schools during their robot design, organizing the competition events, designing scoring sheets, etc..

I. Description of Course Format

During spring 2010, the section of ENGR 1315 offered by the author as a service learning course was the only section being offered, i.e. all students who wanted to take ENGR 1315 during that semester had to enroll in this section. 91 students enrolled in the class, which consisted of two hours of lecture and two hours of lab. The lectures covered an overview of the profession, an introduction to LEGO NXT, Excel and MATLAB programming, a series of invited talks from colleagues in different engineering disciplines, and lectures on standard units and conversions, basic electric circuits, and systems of linear equations. Wherever possible, the GEAR competition was used as an application example. The lab sections were "hands-on" and students participated in wood and metal work, programmed LEGO NXT robots, and performed Excel and MATLAB assignments. The labs were purposefully scheduled during the afternoons, such that students could mentor GEAR robotics teams during this time period once the competition had started. The grade of the course consisted of the following components:

- 3 exams 10 points each
- homework / computer lab exercises 20 points
- service learning / alternative project 50 points

II. Service Learning Project

The GEAR competition for local elementary and middle schools served as service learning projects and students were expected to participate in:

- The preparation of the competition (reading and understanding game rules, building game pieces for school teams, setting up game tables). The construction of the game pieces was performed during lab sessions.
- The organization of the competition (kick-off event, trial run, game day). All these events were on Saturdays and sign -up sheets were provided electronically through Blackboard [11].
- Mentoring school teams (school teams typically met 1-3 times during the week after school for an 8 week time period; some teams met during the regular school day). Students could choose from a list of 20 local and up to 60 miles away schools. The schedules of the schools robotics clubs were made available to the students and the students again signed up electronically for a school through Blackboard.

Students were expected to complete 15 hours of service-learning work for the course. They received training in designing and programming LEGO robots during the first weeks of the course and mentor training prior to mentoring a school team. All mentors had to go through criminal background check administered by the school districts.

In addition to service learning activities, students were required to complete five reflection papers and had to document the hours spent mentoring school teams in the form of a journal.

The grading criteria for the service learning project were:

- 15 hours of documented service learning work 15 points
- 5 reflection papers 6 points each
- Peer evaluation 2 points
- Teacher evaluation 3 points

The reflection papers covered the following topics:

- Advertisement of the GEAR competition in the community with the purpose to either recruit new schools by talking to principals and teachers, or new sponsors by approaching local businesses. Students had to document
  - how they decided whom to approach
  - what information about GEAR they considered important
  - how they contacted the customer
  - what responses they got
  - what they would do differently a second time
- Evaluation of their school teams' design process for one of the GEAR competition tasks. In a 400 word essay they had to describe their design steps, addressing how they brainstormed, planned, made decisions, built, tested, evaluated, troubleshot, and improved their robots.
- Documentation of a GEAR event (kickoff, trial run, game day) summarizing the purpose of the event, time and location, groups of attendees, agenda, responsibilities during the event, highlights or problems, and what they would do the same way or change if they had to organize it the following year.
- Evaluation of their role as a mentor by describing an event where they were successfully helping their team and how they were able to do it. They also had to describe an incident where they felt were not able to help their team and analyze why that happened.
- Revisiting a list of skills they considered important for engineers at the beginning of the semester and describing which skills they needed as mentors and how proficient they felt in those skills.

III. Alternative Project

Students who opted not to participate in the service learning project were offered an alternative assignment which consisted of developing an 8 hour LEGO NXT kit based lesson plan focusing around a science topic addressed in elementary or middle school (e.g. gears, angles, trigonometry, and velocity) aiming at teachers with no or

limited experience with LEGO robotics and NXT programming. They had to hand in 10 papers describing:

- Motivation, overview of the topic chosen and how to incorporate LEGO NXT kits;
- Lesson plans for each of the 8 lessons including motivation, building/programming concepts, expected learning outcomes;
- Test and evaluation of lesson plans.

The alternative assignment was graded as follows:

• 10 papers	3 points each
• Oral presentation of lesson plan	5 points
• Peer evaluation (from within group)	2 points
• Class evaluation	3 points

From the 91 students who enrolled in the course 6 opted for the alternative assignment.

IV. Evaluation

Overall, students engaged in the service learning project. They took their mentoring assignment seriously, regularly showed up at their schools, and received excellent evaluations from their school teachers. Several students mentioned in their reflection papers that they were not convinced about the usefulness of the assignment but realized through the semester how their communication skills, professionalism, patience, and engineering design skills were challenged through the mentoring experience. Only one student mentioned at the end of the semester that he was not motivated during the mentoring and admitted that it negatively impacted his performance. At a few schools with several mentors (3-4), having a group of mentors reduced their effectiveness, since they were more occupied with themselves than with their teams.

Students also engaged in organizing the GEAR events, but not at the level the author expected them to. For most of them is was simply a class assignment, maybe even a tedious one, since they had to be present on a Saturday, and they did not worry about ruining an event for 400 participants who put a lot of time and effort into the competition through sloppy organization. Student GEAR event reflection papers revealed that the students were surprised about the size of the event. Students who participated in trial run criticized the amount of chaos during setup, which was caused by a group of students not showing up the evening before trial run to transport game tables to the event such that they had to be brought in during the morning of the event. Students who were assisting during game day positively commented on the organization of the event. A general criticism was the lack of communications between the instructor and the students. While the author knew well what had to be done during setup and cleanup of the events, many students simply stood around not knowing what their role was. Others complained that they were the ones doing all the work while their classmates were standing around and watching them.

The envisioned lab format, where the students, split into two sections, would learn to program the LEGO NXT kits, build game pieces, and then mentor school teams during the time that they would normally spend in lab, did not work well. During the first four weeks of the semester, before the competition started, too many tasks had to be accomplished. It took longer than anticipated to build the game pieces (cut wood, drill holes, nail items together) and the quality of the pieces varied largely. Also, students were only exposed to LEGO NXT programming for three weeks, which did not sufficiently prepare them for the design challenges they encountered at their schools. Several students commented that they did not feel prepared enough and often were not able to help their teams. Due to the limited number of LEGO kits available, NXT programming could not be performed during the lectures nor could students take the LEGO kits home.

The lab sections were purposefully scheduled in the afternoons at a time when most school robotics teams would meet to ensure that engineering students would have time to mentor schools during this time period while being excused from the lab. Many but not all schools scheduled their meetings accordingly. However, only about half of the students in each lab section mentored school teams during the time of their lab while the other half still came to the lab sessions. This left the instructor with the dilemma of having to design activities to engage the students who were present during the lab sessions that could be missed by the ones who were mentoring at the schools. Topics of those lab sessions were mostly additional opportunities to program the LEGO NXT kits, and allocated time for Excel and MATLAB assignments that were well-documented such that students who were absent during the lab could perform them independently at home.

While the author wanted to exploit the GEAR competition to teach various skills required in engineering, students quickly got saturated and instead wanted to perform some "real engineering" tasks. When, e.g. the author taught a lecture about the design of spreadsheets and relative and absolute addressing in Excel, the students stayed interested up to the moment when she used the GEAR scoring sheets as an example for a spreadsheet. The facial expression and mumbling going through the class at that moment reflected a "not-that-stupid-GEAR-competition-again" attitude among the students.

MODIFIED SERVICE LEARNING CLASS 2011

The author felt that the mentoring experience was a success in teaching engineering freshmen a set of important skills that are typically not addressed in the classroom, including communication to a broad audience, professionalism, critical thinking, reliability, and leadership. She thus decided to teach another section of ENGR 1315 with service learning designation during the spring of 2011, this time in parallel to two "traditional" sections of the same course. Since all three sections shared a set of 8 common lab sections, i.e. students signed up for lab sections independently of the class section

they chose, dedicating the lab section to LEGO robotics, was not possible. All lab sections were administered by one instructor and they covered a series of assignments through which students learned how to program in Excel, MATLAB, and Mathcad. Also, all sections used the same textbook [12].

Since students could choose between a "traditional" and a "service learning" section of ENGR 1315, the author informed all undergraduate student advisors in the college about the nature and content of the "S" section. A discussion during the first class session, however, revealed that students were not aware of this difference but simply chose this section because it fit best into their schedule. To avoid a huge class, the enrollment was limited to 40 students and 26 students actually enrolled in the "S" section.

The service learning project was reduced in scope to mentoring K-8 school teams participating in GEAR with their LEGO robotics design. Being familiar and thus more efficient with the criminal background check procedures that the schools required, most engineering students started mentoring at the schools two weeks prior to GEAR kickoff event. During this time they assisted teams and teachers with introductory LEGO robotics, i.e. building a robot first, then programming the motors to move it, and finally adding sensor input to it. They also participated in GEAR events, being part of their school teams. The organization of the GEAR robotics events or the construction of the game pieces were no longer part of the service learning project. Instead, these tasks were performed by undergraduate students who took a freshman level introductory engineering class in the previous year and who were paid hourly for their efforts.

Most service learning reflection papers remained the same as in the previous year. The advertisement of GEAR, however, was dropped, since it was not effective. With the smaller class size, most students were the only mentor at their school, thus peer evaluations within the group were no longer possible. Instead, students would read one of their classmates' journals and comment on similarities and differences in mentoring responsibilities at the different schools.

To overcome the limited experience in programming and designing LEGO NXT robots, in-class activities were designed using the LEGO NXT kits. A sufficient number of LEGO NXT kits were set aside for these semester long in-class activities, which included:

- Motion and sensor input: Design and program a LEGO NXT robot such that it
  - moves straight forward for 3 feet and then stops
  - goes around a square with an area of 9 square feet
  - moves forward on a white surface and stops when it detects a black line with its light sensor
  - goes forward until it bumps into an obstacle and then backs up one foot
  - uses the ultrasonic sensor to detect an object and plays an alarm sounds when the object gets too close
- SOLVEM design methodology: The textbook [12] introduces the engineering problem solving process using SOLVEM methodology, which consists of a **S**ketch, **O**bservations and Objective, **L**ist of **V**ariables and **E**quations, and finally the **M**anipulation of equations to find the desired results. Students practiced SOLVEM through the task having the LEGO robot move along a given regular polygon. They had to perform sketches, identify required variables and equations, measure the sides of the polygon, and manipulate their equations to determine the motion of the wheels (in number of rotations) to go straight and to turn. Only when they had finished all steps of SOLVEM were they allowed to program their robot and perform the experiment.
- Data collection and statistical analysis: Students performed their own data collection by measuring the time it took their robot to travel a distance of 12 feet at various power levels, which determine how fast the motors turn. They repeated each experiment three times. The data from all students was collected in a speadsheet and for each power level students had to calculate means, medians, and standard variation and had to plot histograms. They also had to relate the power level to the velocity of the robot. They were asked to evaluate the variance when comparing different robots or repetitions of the same experiment using the same robot. Students summarized their results in a powerpoint presentation and presented in class.
- Acceleration, velocity, and displacement: To prepare for this assignment, students learned advanced LEGO NXT programming principles that included data wires and enabled them to adaptively change the inputs and read the outputs of the motors and sensors. During this assignment they had to program their robot such that it went forward for 10 second starting at power level of one and increased the power level by one every 0.1 seconds. They were then asked to design an experiment that allowed them to determine the distance the robot had traveled as a function of time that had elapsed. They performed their experiment, collected data, and gave an oral presentation that explained not only the design of their experiment but also how acceleration, velocity, and distance relate to each other in theory and how their experiment confirmed these relationships.

Through these in-class activities the students experienced the LEGO NXT kits as a valuable piece of equipment to perform experiments that relate to math, science, programming, and design concepts. The experiments helped them to visualize theoretical relationships.

CONCLUSIONS

Service Learning can be successfully employed as a teaching method in freshman engineering classes. Mentoring elementary and middle school students during an 8 week LEGO robotics competition teaches students communication

skills, critical thinking, problem solving, professionalism, and leadership, i.e. skills that are hard to teach in a classroom setting. At the same time teachers appreciate the presence of the engineering students in the classroom, often the only exposure to engineering for both, teachers and students. Being considered as the "engineering experts" by their school teams, as opposed to "inexperienced freshmen who do not have essential skills yet", which is feedback freshmen typically receive at the engineering job fair, boosts their confidence to succeed in their major. The in-class activities and the service learning project need to be balanced carefully such that students understand the importance of the project to their engineering career but are also exposed to more "traditional" topics in an introductory engineering course.

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