2006-2228: USING SERVICE-LEARNING TO INTEGRATE K-12 OUTREACH INTO A FIRST-YEAR ENGINEERING PROGRAM

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Using Service-Learning to Integrate K-12 Outreach into a First-Year Engineering Program

Abstract
Engineering educators face many challenges in designing first-year programs and outreach programs for K-12 students. First-year students need real experiences early in their program to allow them to learn to address large and open-ended and large problems. Pre-college students need opportunities to learn about and even experience engineering. Especially challenging are programs for urban students that address recruitment and retention. In 2003 the Department of Engineering Education at Purdue University began a partnership to address both the needs of pre-college and first-year engineering students. First-year engineering and science Multi-Cultural Learning Communities partner with an outreach program, Science Bound, which works with junior and senior high school students from a large urban school system. This partnership uses a service-learning model to engage the first-year university students with the high school students that is meaningful for both groups. 120 students from engineering and science and over 200 junior and senior high students, from 8 urban schools have participated in this program. This paper will focus on the engineering aspect of the K-12 outreach program and the experiences of both the first-year college and high school students. Both qualitative and quantitative assessments of will be reported and have shown initial success.

Introduction
Modern society continues to rely on research and technology related to science, technology, engineering and mathematics (STEM) which is driving an ever increasing demand for qualified professionals. A major area of concern over the last two decades has been the declining interest in the engineering fields among pre-college students and the continued underrepresentation of women and minorities. The efforts of the past two decades have produced gains in some areas, but women, African Americans, Hispanic Americans and Native Americans continue to be underrepresented. Reports by the National Science and Technology Council[1] and the Commission for Advancement of Women and Minorities in Science, Engineering and Technology [2] identify the societal perils of continued disparate representation across engineering and the STEM fields. Continued underrepresentation has dire implications for the future of the technical workforce as the demand for qualified professionals will outpace the available pool if the demographics do not change[3]. The additional human cost for unequal access that is characterized by underrepresentation makes the issue compelling and critical for society and the STEM fields in particular. Thus, beyond the moral and ethical implications of unequal access, which would be a sufficient cause for concern by them, underrepresentation in engineering and the STEM fields as a whole becomes a critical and compelling issue for society in general.

The compelling nature of the issue has generated a great deal of effort over the past two decades and resources have been dedicated to increasing the representation of these underrepresented groups. These efforts have included programs targeted at special populations with the creation of minority and women's programs in engineering, technology and science; summer and outreach programs for K-12 student; summer bridge programs and larger curriculum reform efforts including the NSF Coalitions[4]. Many outreach programs have been developed by the

engineering programs to help develop a "pipeline" in engineering. While these efforts have seen success, women and minorities continue to be underrepresented and only account for a small percentage of degrees in engineering and science. A comparison of the 1982 and 2000 NSF *Women, Minorities and Persons with Disabilities in Science and Engineering* reports shows that despite the efforts over the last two decades, the main goal of increasing the underrepresented minorities participating in STEM undergraduate programs remains[5,6].

Approaches that have been cited in the literature as positive steps toward encouraging women to stay in STEM fields include framing science in its social context; stressing general educational goals, including communication, in engineering education; employing cooperative, interdisciplinary approaches; and undertaking problems with a "holistic, global scope" [7,8,9]. Research that has been conducted suggests that many of the same factors are relevant for attracting and retaining minorities[10,11,12]. A pedagogy which integrates all of these aspects and has proven to be effective in enhancing learning is service-learning.

Sue Rosser, Dean of Ivan Allen College at Georgia Tech, challenged the American Society for Engineering Education during her address as a Distinguished Lecturer at the 2002 ASEE Annual Conference to rethink the way in which STEM students learn as a significant step to address the issues of underrepresentation. She outlined how the time was right for rethinking the curricula in STEM fields. In engineering, ABET's EC 2000 provided an opportunity to redesign the curricula to capitalize on existing literature to reduce the barriers for underrepresented populations within science and engineering [8]. She provided an outline of what is known about science education and how it can be transferred across STEM disciplines. In the discussions following her address, she specifically identified service learning as one potential means of integrating important aspects into the core undergraduate curricula.

This paper will explore how an outreach program in engineering and science can be implemented using a service-learning model with first-year students.

Purdue University's First-Year Engineering Program

Purdue University's Department of Engineering Education has responsibility for all of the approximately 1650 first-year engineering students. All engineering students are required to complete a common first year core of classes shown in Table 1 before matriculating to their respective engineering major. Minimum grade levels are established for matriculation to the major of their choice. The department includes ten tenure track faculty and four academic advisors. This department has the responsibility for all of the academic advising for first-year students and primary teaching responsibility for the engineering lectures, seminars, help and assistance courses as well as the first engineering course, ENGR 106 - Engineering Problem Solving and Computer Tools.

Table 1: Purdue University First- Year Engineering Curriculum

Fall Semester	Spring Semester
Calculus I	Calculus II
Chemistry I	Chemistry II or Computer Programming
Engr Lectures (+ seminar option)	Physics (Mechanics)
Engr. Problem Solving and Computer Tools	English or Communications
English or Communications	Optional Electives
Optional Electives	

Integration of Service-Learning

A number of options for implementing service-learning into the first year have been considered. The nationally recognized EPICS program at Purdue has demonstrated significant success but enrolls about 300 students a semester. With over 1600 first-year students each year, it is not a viable option to simply add the first-year students into the EPICS program. Options have therefore been created for first-year students to participate in one semester service-learning opportunities [13]. These started with single courses but it became apparent that with the current curriculum there was not one single course that could be adapted easily for a quality service-learning experience. There were, however, several courses that could contribute to such an experience.

The solution has been to leverage the learning community initiative within Purdue to link three classes together and use the service-learning experience as the curricular connection between the courses. This has been used successfully and has found to be beneficial both for facilitating service-learning and for the scaling up of the learning community [14]. This discussion will focus on the one of the community partnerships that was linked with the Science Bound outreach program.

First-Year Learning Communities

Engineering has been a major participant in this initiative. For the fall semester of 2005, approximately 340 engineering students were enrolled in one of three learning communities directed by the Department of Engineering Education. Each learning community consists of a series of linked classes where cohorts of students are registered together, co-curricular activities. Some learning communities also offered a residential component where students are assigned to the same floor of a residence hall. Service-learning has been integrated as a curricular tie for all three of the First-Year Engineering Learning Communities.

Students elect to participate in a learning community. Information about the learning communities is distributed in the spring and students register for them as part of the class and housing registration process. The expectation of a service-learning project was made clear to each participant. The honors learning community is only open to students in the Engineering Honors Program while the Network and IDEAS learning communities are open to all first-year engineering students. All of the students in the IDEAS and Network learning communities were

placed in the same lecture division of the first engineering course (ENGR 106 – Engineering Problem Solving and Computer Tools), which facilitated the service-learning and a sense of community among the engineering learning community students. The Honors Learning Community was not formally connected with Network and IDEAS.

IDEAS is a multicultural-themed learning community (MLC) that was also paired with a MLC for science students called Bonding in a special section of chemistry. This chemistry lecture was limited to the 48 students in the two MLC's and provided opportunities for community building across the MLC's. Seminar classes were also part of the MLC and were scheduled at the same day and time to make joint meetings possible. We capitalized on the connections between the two MLC's to bring them together for a joint outreach service-learning project that worked with the Purdue sponsored outreach program with the Indianapolis Public Schools called Science Bound.

Table 2: First-Year Engineering Learning Communities

Learning Community	Theme	Linked classes	Residential Component	Service-learning
Honors	Honors	Honors Seminar Hon. Engr. Problem Solving	Required	Required
Network	Service-learning	Engr. Problem Solving Communication Seminar	Optional	Required
IDEAS	Multicultural and Service-learning	Engr. Problem Solving Chemistry Seminar	Required	Required

Science Bound

Overview

The Purdue University Science Bound program [15] is an outreach program that mentors 8th through 12th grade students at Indianapolis Public Schools (IPS), encouraging them to enroll in classes and pursue careers in science, engineering, technology, and math/science education. Those IPS students who complete the 5-year Science Bound program and gain acceptance to Purdue University in an approved field receive a full-tuition scholarship to Purdue for eight semesters. Around 50 students from the 24 IPS middle schools are added to Science Bound each year. Criteria for selection are based on national test scores and the students' potential to succeed in the program.

Twenty-two mentor teachers — one from each of the 24 middle schools and, eventually, the five high schools in the IPS School Corporation — participate in professional development. The program strengthens their teaching methodology and instructs them in cutting-edge technology and curriculum integration of advanced mathematical and scientific content. The mentor teachers

are responsible for the implementation of the Science Bound program with students in their respective schools, in addition to their classroom teaching responsibilities.

The teacher-mentor in the respective building facilitates bi-monthly after-school programs for the Science Bound students. The goal of the after-school mentoring program is to:

- excite and educate students about science, mathematics, engineering, and technology careers;
- increase students' math/science content knowledge and problem solving skills;
- provide an avenue allowing students to consider science, engineering, and technology as a way of understanding the world in which they live;
- provide accelerated projects-based learning experiences;
- provide instruction on and experience with research grade instrumentation and participation in research projects;
- Prepare Science Bound students for a successful college experience.

Purdue University offers Science Bound students on-campus activities, which also involve their families and mentor teachers. These range from attending campus sporting events to weeklong residential academic summer camps. The purpose of these activities is to familiarize the students and their families with college life and to provide a summertime continuation of the academic after-school program. This discussion will focus on the on-campus activities and interactions with first-year engineering and science students.

Integration of Science Bound and Engineering Learning Communities

In 2003, discussions began about how to integrate the Engineering Learning Communities and the Science Bound program. The goals of the two appeared complimentary and the leaders of both agreed that collaboration could benefit both. It was agreed to start with a simple and small initial project that had a high chance of success and build on that experience for further collaborations.

In the fall 2003, one of the sections of the Network Learning Community was given two tasks as part of their service-learning project. First, they had to design a hands-on project for students visiting campus on a football Saturday and design an introductory program for the parents. The second part of their assignment was to perform an evaluation of the experience and then to make recommendations for the future years.

The experience of 2003 was positive but not without challenges. The hands-on project was a bridge building activity with tooth picks and marshmallows. The students enjoyed the project but it was difficult to stay within the time we had before the football game. The parents program was great and gave us a chance to talk about what our first-year students were doing and why the service-learning experience was part of their engineering education. The students provided valuable insights into their own limitations and constraints of the first-year students for our planning.

At the end of the first year, it was agreed to continue our collaboration but with a few changes. The first part was a change in the learning community matched with Science Bound. We moved the project to the MLC's (IDEAS from engineering and Bonding from Science). As mentioned earlier, IDEAS and Bonding shared a common chemistry class and had seminar classes that were scheduled at the same time. In 2003 IDEAS had a service-learning project with a local community center while Bonding had no service-learning experience. The observations of the chemistry instructional team in 2003 were that the service-learning experience provided a much richer sense of community among the students who had the service-learning experience. Since Science Bound is an engineering, science and technology outreach program, we could match both up in a common project that could better serve Science Bound and would also bring the two communities together. It was also decided that we should move the activities away from a football Saturday to give the students a longer experience. We divided a day into an engineering section in the morning and a science section in the afternoon. We also felt it was important to get the students from our campus down to visit the Indianapolis Public School students at their own school to give the Purdue students more insight when they designed the day of activities for the campus visit.

For the fall 2004, we brought the students from IDEAS and Bonding together using the common seminar times and introduced them to Science Bound and the two. The first-year students were told that they would be working with Science Bound students in two ways.

The first way was having the first year students go to the high schools of the Science Bound students in Indianapolis. Students were expected to conduct short engineering and science projects which would engage Science Bound students. These projects were designed to less than two hours in length. They included projects like building simple structures to support a load, designing or creating a vehicle to support an egg dropping from a height.

Students wrote a short proposal on the type of projects that were planned. In addition to the planned proposal students were required to verbally discuss how they would talk about themselves and facilitate questions and discussion. Six high schools participated in the Science Bound program and each was visited by one student team that was comprised of both engineering and science students. Each team picked one of an already established date we had already arranged with the Indianapolis schools.

Before students conducted their activity at the schools, we discussed and conducted activities on multiculturalism and communication. These activities included social and ethical issues that engineers face in the profession. In addition students were engaged in activities which required them to visit and talk with people of different ethnic origin.

Students who are part of Science Bound are required to participate in a specific number of scheduled activities. To prepare the Science Bound students for their first meeting with the first year students, each of the six high schools in the Science Bound program informed their Science Bound students that they would be doing activities with first-year engineering and science students at a specific time and date. Students were informed that this specific activity would focus on engineering and science.

As a result of this first meeting between first year students and high school students we intended to begin to fulfill several goals including goals that are consistent with ABET criteria and some general goals of K-12 outreach. These goals are:

Goals for first year students

- To get first students experience in learning some engineering and science.
- To get first year students experience in how to address open ended problems.
- To get first year students an experience of what it means to think about the client.
- To get first year students to understand some legitimate social issues that engineers and scientists might face.
- To get first year students to begin to understand what is the difference between engineering and science.

Goals for K-12 students

- To get high school students excited about engineering and science.
- To make allow Purdue Engineering to make an initial connection with the high school students.
- To teach high school students something about engineering and science.
- To get high school students more comfortable and more open to talk and ask questions for a second meeting.
- To get high school students to begin to understand the difference between engineering and science.

The second aspect of the service-learning project involved developing a more extensive and intensive day for the first year and Science Bound students. The high school students would come to Purdue University for an all day activity conducted by the IDEAS and Bonding students. Students divided that the day into two separate parts. The first part of the day focused on engineering and the second part focused on science. We separated the engineering (IDEAS) and science (Bonding) students into separate working groups for this part of the project. Students had to write and present detailed proposals on what they were planning to do for the day, how they planned to execute the tasks for the day, what materials they need to execute their plan, how their projects related to engineering or science, as well as what service are they providing to the community by conducting their projects. For each group, students received a budget of about $1000 dollars. In addition, the MLC engineering and science groups were expected to collaborate with each other to discuss and provide to Science Bound students of how engineering and science are similar and different.

For the First-Year Engineering/Science Days, the high schools of their Science Bound students informed the Science Bound students about coming to Purdue University. The Science Bound students who were interested in coming to Purdue were required to have permission slips from their parents to go to participate in the event. Those who signed up were explained and given an itinerary of the day's events. Any parents or teachers of the Science Bound students were also allowed to attend the event.

The program for the day on campus included:

9:00 Arrive on Campus, breakfast and introduction
9:30 Engineering Projects
High school students are split into three groups and rotate between three projects conducted by the Purdue first-year engineering students
12:00 Lunch with all high school students and Purdue engineering and science students
Lunch speakers are engineering and science students
1:00 Science Projects
High school students are split into three groups and rotate between three projects conducted by the Purdue first-year engineering students
4:30 Depart Campus

Sample projects during the day included:

- Chemical equilibrium experiments that show phase and color changes.
- Rubber-band power cars to discuss energy transfer.
- Dissection of disposable cameras
- Design and build wind-powered cars tested with an exhaust fan as the wind source.
- View it/build it – observe a structure and document how to build it. Handing it off to another group to manufacture and test.

Evaluation

There were 39 Science Bound students who attended the First-Year Engineering/Science Day 2004. Following the Science Bound students' experience at Purdue, Science Bound students were asked a series of questions in the form of surveys and open ended questions concerning the First-Year Engineering/Science Day 2004. In addition to first year students normal reflection activities incorporated as a part of service-learning, first year students were also interviewed about this particular service-learning experience.

The results of these questions showed to be overwhelmingly positive for the Science Bound and the first year students. Based off of the positive feedback from both the Science Bound and the first year students we collaborated and worked with Science Bound and their students again in 2005 using basically the same format but with different projects since some of the students returned from the previous year.

The overall results of the evaluation showed very favorable results. The evaluations were the overall measure in which we based the success of our implementation of service-learning in K-12 outreach. Evaluations of the K-12 participants and the first-year engineering students were conducted for the fall 2004 and are reported here.

<u>Evaluations of K-12 Participants</u>
To get a better understanding of what the Science Bound students thought about the First-Year Engineering/Science Day, students were asked to rate the engineering group presentation, the science group presentation, the organization of the day's events, and how useful did you find the activities on a five point-Likert scale, Figure 1. The five point-Likert scale was rated as 1 being

poor to 5 being excellent. There were 39 Science Bound students who attended the First-Year Engineering/Science Day.

Out of the 39 students, 29 of the Science Bound students responded to this part of the evaluation of the First-Year Engineering/Science Day. We were very pleased that we obtained a 74.3% response rate from the Science Bound students. Typically we would expect a 60% response rate for N = 39 to assume a representative sample population. Over 69% of the students who responded reported excellent to the targeted questions.

TARGETED QUESTIONS	**POOR 1-2**	**FAIR 3-4**	**EXCELLENT 5**	**N**
1. Overall rating for FIRST-YEAR ENGINEERING group?		28%	72%	29
2. Overall rating for FIRST-YEAR SCIENCE group?		31%	69%	29
3. The organization of the day's event?		24%	76%	29
4. How useful did you find the activities?		31%	69%	29

Figure 1: Five point-Likert scale, responses from Science Bound students on First-Year Engineering/Science Day, fall 2004.

The Science Bound program allows those students who meet all program requirements 100% tuition assistance. Students who attend a major university often discuss their concern about how to matriculate through a large university environment. Based off of Science Bound student interactions with first year students, it was questioned as to whether Science Bound students would want one of the first year students as a student mentor, Figure 2. Science Bound students responded very favorable to this idea of having a student mentor. Data indicates that 76% of Science Bound students wanted a first year student as a mentor. Student responses indicated that 17% said no, they would not want a mentor.

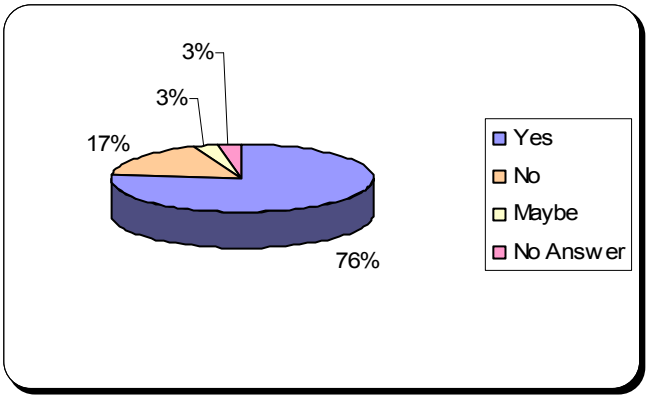

Figure 2: Science Bound student responses to would you like a Purdue student as a mentor.

In addition Science Bound students were asked open ended questions. The Science Bound students were asked if they had any other comments that they would like to share about the First-Year Engineering/Science Day. Student responses could be grouped into four (4) main responses:

(1) The first group of responses was that the first year students were friendly and helpful. Students wrote down comments such as "they treated us friendly, you are nice and helpful keep up the good work, and thanks, good presentation".

(2) The second group of responses was that the day was fun and that they wanted to do it again. Comments were made such as "they were fun and other comments such as I enjoyed all the projects and presentations and I would do it again".

(3) The third group discussed what they learned. Students stated, "I learned that it is much more to taking pictures than it seems, I learned about reactions and equilibrium, and I would like to thank them for giving me the college aspect of everything we did".

(4) The fourth group of responses involved informing the first year students on improvements that could be made on the First-Year Engineering/Science Day. Science Bound students gave comments such as "do more building and destroying, have repeated demonstrations, get better food, and do less walking and more activities".

It is also important to note that a couple of students did mention that they thought the day was good because they made some friends. It would be very interesting to find out why this was important to those students. Due to time constraints and student anonymity issues we were unable to probe further into what type of effects that this had on those students.

First Year Interviews

To get a better understanding of what the first year students really thought about the first and second occasion with the Science Bound students we conducted 15 in-depth interviews. There were 15 students out of the 35 total students interviewed. This accounted for 50% of the true population. Results from these interviews indicated that students really enjoyed working with the Science Bound students. Interviews also revealed that students had to become more aware of the Science Bound students needs in order to have completed successful projects. Below is given an in-depth look into what a student did and thought about their interactions with the Science Bound student on the first and second occasions/meetings. This is a good representation of what many of the 15 students interviewed thought about during the entirety the program.

Student talking about first meeting with Science Bound students when first year students went to the high schools:

This engineering student describes the work stations that they generated for the students and his excitement with how creative the high school students were with their projects:
We had a station for mechanical and aeronautical, we had a station for chemical and electrical, we had a station for civil and industrial engineering, and our section was aeronautical and

mechanical and we were basically trying to set up something where we could combine both aeronautical and mechanical engineering into one thing, you know they would have to use components of both, so I suggested ah-ah sail-powered car, so it would be aeronautical component would be the sail, and the mechanical component would be the design of the chassis of the car; and ah I think the best part about the Service Learning Project was when I saw this design that this kid came up with for this-this car - actually it wasn't specifically this kid it was actually like a basically like a little team, it was like twenty people just like on the ball, you know, and I just saw the design for this car, and I was like, that's some creative stuff I mean, I mean that's-that's going to work. And then you put it up there and tested it out, and it went so far - I was like "wow" – that was great. I was like, hum, maybe ah I should do that next time – you know it-it was good to see that there's you know there's creativity out there. And that was beneficial to me a lot, I liked it.

Student talking about second meeting with Science Bound students Purdue University:

The project actually presented a couple of problems because it was kind of like, you know, how can we make these kids like not be bored stiff, but how we tell them something that they haven't already heard. And that was actually one of the main concerns of the project because these weren't just like kids off the street. You know, - these were kids that have been in the program for a couple of years – they'd already been exposed, so it was really trying to, we were just trying to raise the level of their interest. So, one of the main things we were trying to do in the project was not only tell them something that they hadn't heard before, but potentially show them something that they had not seen already. We're not just doing this, we're doing it to try to impact somebody else, so throughout the entire design of the project we were just like keeping those things in min.

Conclusions

The integration of a pre-college outreach program and the first-year learning communities in engineering and science has been a successful partnership. It has provided a meaningful way to bring the science and engineering students together and to connect the courses in the learning communities. It has provided the outreach program with a reliable source of projects and first-year students. The partnerships provide benefits to all three programs which has been a major reason for continuing the partnership. The responses from the student participants and the instructors have been positive. Plans for 2006 are to continue to evolve the partnerships. We are looking at ways to connect the college students with the high school students on a more consistent basis rather than just during the two projects. Electronic mentoring will be explored for the fall of 2006. We will also look at developing materials or a workshop for the teachers that the science students would lead in addition to the project time with the students.

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