AC 2008-1906: TEACHING ENGINEERING IN HIGH SCHOOL USING SERVICE-LEARNING: THE EPICS MODEL

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Teaching Engineering in High School Using Service-Learning

Introduction

Over the last 20 years, a great deal of time, effort and money have gone into increasing interest in engineering among pre-college students, with minimal results. Overall, interest in engineering has been flat or declining. The number of women and minorities within engineering continue to be underrepresented compared to their share of the overall population. Many are calling for new approaches to engage young people, including an active investigation by the National Academy of Engineering.

While interest in engineering has been declining, interest by young people in community activism through community engagement is increasing exponentially. The number of teenagers who volunteer, for example, has doubled in the last ten years. Civic engagement among pre-college students is at near historic highs. In light of these current trends it is becoming more obvious that young people want to be engaged and participate in something that they think will make a difference in their community. Through anecdotal evidence it appears that these students are not, however, connecting this interest in helping their community with engineering. This is one of the questions that we begin to investigate in this paper to begin to test this anecdotal evidence.

Connecting engineering and science as fields that benefit people has long been cited in the literature as a way to increase interest among women[1-4] as well as underrepresented populations[5-7]. Experiences in service-learning programs at the universities have confirmed this trend. The Engineering Projects in Community Service learning (EPICS) Program at Purdue University[8,9] has reported higher percentages of underrepresented students and chapters of Engineers Without Borders have reported many chapters being at or near gender balance.

While the university programs are an asset, to impact the pipeline of engineering students would require pre-college programs to draw students into the college pipeline. Drawing students into this pipeline requires students to have a basic knowledge of engineering, to be interested in engineering, and dissipating the current views of what it means to be an engineer. This paper will describe how a service-learning model has been adapted to the high school environment to encompass these aspects as students are introduced to engineering.

Program Description

EPICS is an innovative engineering-based, design program that uses a service-learning model to meet the educational needs of undergraduates and the compelling needs of the local community. Founded in 1995 in Electrical and Computer Engineering at Purdue University, it has grown to be a multidisciplinary program engaging over 30 different majors per year. The model has spread to other campuses and is active at 20 universities around the country and aboard.

In EPICS, students earn academic credit for their participation on design teams that solve technology-based problems for not-for-profit organizations in the local community. The teams are: multidisciplinary – drawing students from across engineering and around the university; vertically-integrated – maintaining a mix of freshman through seniors each semester; and long-term – each student can participate on a project several semesters. The continuity, technical depth, and disciplinary breadth of these teams enable delivery of projects of significant benefit to the community. The model that guided the program was to involve each student for several semesters or even years on the same long-term project, so that each student would experience varying roles over the course of the project.

The EPICS program is built around the concept of long-term partnerships between student teams and not-for-profit organizations in the community. Community service agencies face a future in which they must rely to a great extent upon technology for the delivery, coordination, accounting, and improvement of the services they provide. They often possess neither the expertise to use nor the budget to design and acquire a technological solution that is suited to their mission. They thus need the help of people with strong technical backgrounds. Moreover, the community service agencies will ultimately deploy the teams' systems.

Each team and its community partner work closely together to identify and solve the partner's technology-based problems. The projects fall broadly in four areas: education and outreach, access and abilities, human services, and the environment.

High School Model

It is a natural step to expand on the concept to the high school level to provide an introduction to engineering using service-learning design. Transferring the college-level model to a high school environment required restructuring to provide the engineering background and technical skills required by the individual project(s) and to acknowledge pedagogical needs of younger adolescents. Instructional teams were formed using high school teachers and mentors from local industry and/or university programs.

The first pilot high-school program was initiated by alums at Bedford North Lawrence High School in Bedford, Indiana[10]. With support from their employer, Crane Naval Surface Warfare Center, and the local American Society of Naval Engineers (ASNE) chapter, they established a partnership with a physics teacher to bring EPICS into the high school environment. The student team developed a prototype, secured a provisional patent and has filed for a full patent on an assistive technology device. The percent of female participants has ranged from 50-70% over the last three years.

The success of the pilot motivated a grant from the Corporation for National and Community Science (CNCS) Learn and Serve America Program to expand the concept on a national basis. University partners were selected to help identify potential high schools in five states. High Schools were selected in collaboration with the partnering universities. The initial high schools were in proximity to these universities

Key Elements of the EPICS High or EPICS High School Program

- Teacher development- Teachers need to be informed and allowed to understand the thinking as well as structural framework that compliments the EPICS model.
- Curriculum support- Teachers involved in EPICS HIGH may need or want guidance to a way that the course can be taught or just understanding in the form of lesson plans.
- Engineering and Technical Content – Because EPICS projects cross many disciplinary boundaries and require students to apply skills they do not already possess
- Engineering mentors and support – High Schools may not have the mentors and extra support they need to function.
- Community Partnerships- High Schools may need guidance on how to develop community partners in the community.
- STEM Content –students apply their knowledge to solve real problems. In doing so, gaps in the understanding are often exposed and to solve the problems they are addressing, these gaps have to be addressed. This requires additional STEM content to supplement the traditional curriculum
- Funding for projects – Because students deliver real projects, there is a cost for the materials students use the construct their project. These costs are above and beyond traditional costs of a high school class.

EPICS High have the potential to play a role in addressing many issues that are common among pre-college engineering efforts like:

- Increasing interest in engineering
- Increasing visibility of engineering
- Improving STEM education
- Global competitiveness

The service-learning context also gives the program the opportunity to address issues that are important the local schools, including:

- Continued lack of women and underrepresented groups
- Drop out rates
- Building capacity in communities and schools
- Compelling needs of underserved populations

Teacher Development

The first summer teacher development sessions for high school teachers and administrators were held in the summer of 2007. Approximately forty individuals, representing twenty schools attended one of the two, week-long trainings held on the Purdue University campus. Participants developed strategic plans for their programs and went home with the tools and support needed to successfully move their programs forward as they facilitate teams and projects.

The 2007 summer trainings included sessions on topics such as: program management, design, service-learning, assessment, sample projects, and recruitment & sustainability. Evaluation of training participants were overall very positive and contained comments

such as, “I knew very little prior to this training and now feel confident to start EPICS at my school” and “Thank you to all for creating, maintaining, and growing such a great program…I am very excited!”. Summer trainings will continue in 2008 and will be open to any schools interesting in implementing an EPICS program.

The teachers themselves ranged from retired engineers teaching engineering classes, to technology education teachers to science teachers. One school brought a team led by a science teacher and included a technology education, special education and an English teacher. They were looking at integrating the engineering-based service-learning into the science and also the service-learning requirement of the school. Like many schools around the country, they had a service-learning requirement of the students but it was not connected to science, math or pre-engineering.

Teachers were asked at the beginning of the week their expectations and perceptions. These included what participants hoped to gain from the EPICS High School summer workshop. The most common reply was to simply have a better understanding and be more knowledgeable about the program so they could successfully guide their students. Teachers and administrators also hoped to learn more about service-learning and how to connect that to design.

Teachers and administrators understanding of engineering ranged from very little to the feeling that they had a solid understanding. It was interesting to have teachers who did not feel like they really understood engineering and had the opportunity to learn through the service-learning. Almost all of the teachers and administrators strongly felt their students had very little awareness of what engineering was.

At the end of the workshops, they were more convinced that engineering could be fun, and that they didn’t realize there are many career possibilities and variety of engineering fields. One participant commented that, “*the EPICS program is a great introductory opportunity for high school students into engineering fields”*.

Participants’ felt they had a broader view of engineering after completing the workshop. Comments included that understanding the engineering fields required many talents – not just science and math, and a belief that anyone could develop the skills necessary to become an engineer. One participant said that their engineering stereotypes were now gone. Another said, “*My views/ideas of engineering have changed as far as seeing how we can offer engineering as a social responsible career option”*.

When participants were asked after the workshop if they thought that, based on their students’ culture, race, and/or ethic identities in their classroom and school, students would find EPICS relevant, responses were that they hoped EPICS would open their students’ eyes and blur ethnic boundaries. While one participant felt these things made no difference, another felt EPICS was very relevant because their culture is their community.

School models

High schools are implementing their EPICS programs with a variety of models: after school, as a class within the school day, and integrated into a current class. Schools are utilizing EPICS in many ways; as a careers exploration class for students with a variety of interests and strengths, as a technical design course for students with interests in technical fields, and as an early-engineering course. Of these twenty-eight high schools now participating in the EPICS High program current models include; twenty-three in-school programs, three after school programs, and two programs yet to be determined.

The service-learning projects appear to cover the similar four broad areas that are seen at the university level: education and outreach, environmental, access and abilities, and human services. Examples of community partners in these areas include:

- Education - K-12 schools, museums, adult learning programs, after-school programs
- Access and abilities - adaptive services, clinics for children with disabilities, programs for adults with disabilities, assistive technology
- Human services - Homelessness prevention, Habitat for Humanity, family and children agencies, neighborhood revitalization, local government
- Environment - environmental organizations, neighborhood associations, parks & recreation

Example Projects

High School projects currently underway include:

1. **Wastewater diversion/"green" field maintenance project**
   Caseville High School, Huron Intermediate Schools in Michigan

Project Overview: Use, up to now, discarded Department of Public Works water treatment plant, filter rinse water to:

- Irrigate community & school ball fields
- Establish school based experimental garden
- Establish school based experimental aquaculture program to raise and release indigenous fish species in 2 local waterways
- collect, refine and correlate learning objectives for subprojects listed above

2. **McCutcheon Guidance Department ESL Assistant Software**
   McCutcheon High School, Tippecanoe County in Indiana

Project Overview: Create software to aid Spanish speaking families to communicate information with the school and help to enroll students.

- Computers give welcome message and common task menu for Hispanic speakers entering McCutcheon
- Main menu allows parent/student to select from options – enrollment, withdrawal, questions commonly asked
- Completed computerized forms then revert to English for counselors/school use

3. **Aquaponics to improve the air quality for a Nursing Home**
   Frederick Douglass Academy (FDA), Harlem, New York

Project Overview: Harlem has the highest incidence of breathing diseases including

emphysema and asthma in the New York metropolitan area. The students are developing and will install aquaponic systems to produce automated plant systems to increase the amount of oxygen at the nursing home. Elementary and middle school classes will also have projects in the nursing home and will contribute to the project. The Elementary, Middle and High school students are meeting after school twice a week and on the weekends to implement the program. The High school students benefit from working closely with the senior citizens and also by leading and mentoring younger students.

4. Elementary and Middle School Science Materials
Frederick Douglass Academy (FDA), Harlem, New York

Project Overview: Design and build science equipment for the elementary and middle school teachers. The schools in the inner cities lack science infrastructure to engage students in the exciting opportunities in science let alone connecting to engineering. The connection with the high school program to the lower grades creates the opportunity for mentoring by the high school students who are doing the designs for the classes. The result of the project is increase capacity in the STEM classrooms within the school district.

5. Swallow Monitoring Device
Bedford North Lawrence High School, Bedford, Indiana

Project Overview: Design and build a device that will detect when a middle school-aged child swallows and provide feedback to the individual if they have not swallowed in a predetermined amount of time. The application is to help children with certain neurological disabilities that reduce the swallowing reflex which results in drooling, which can negatively impacts their socialization with peers. The device is designed to be able to camouflaged with regular clothing and jewelry so other children would not notice the device and offers current treatments that rely on medications.

Student participants

Fifteen high schools started or continued programs in the fall semester of 2007 with 28 schools now engaged. The schools reported 1177 participating students involving 81 teachers. 50% of the students qualify for free and reduced lunch. An explicit goal of the program was to reach underprivileged populations and the program is starting in that direction.

Another goal is to address the underrepresentation within engineering. Many programs that claim to address this do so in incremental manners. Success is noted when small gains are made. Service-learning has the potential to create programs with the characteristic gender balance as a realistic goal[1-4]. Initial results concur with this possibility with the student participants in the current cohort including equal numbers of males and females.

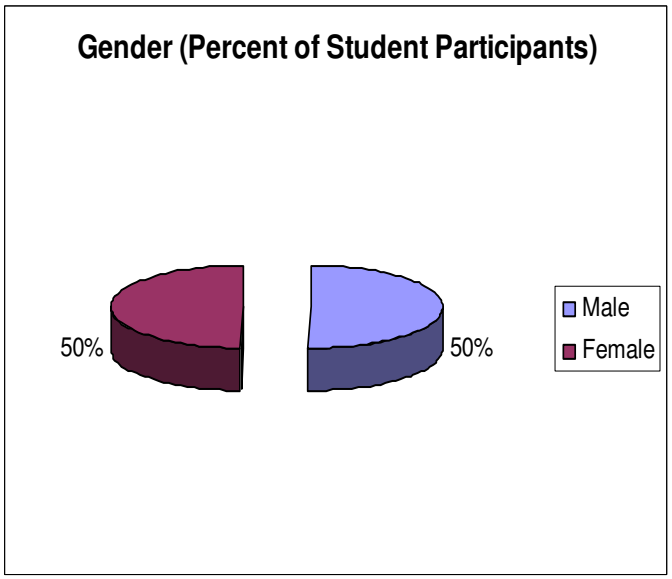

Figure 1. Participation by gender , Fall 2007

The service-learning context also has the potential to address underrepresentation among ethnic and cultural lines and appears to be headed in this direction based on the data shown in figures 2 and 3. Again, this phenomenon is consistent with the literature.

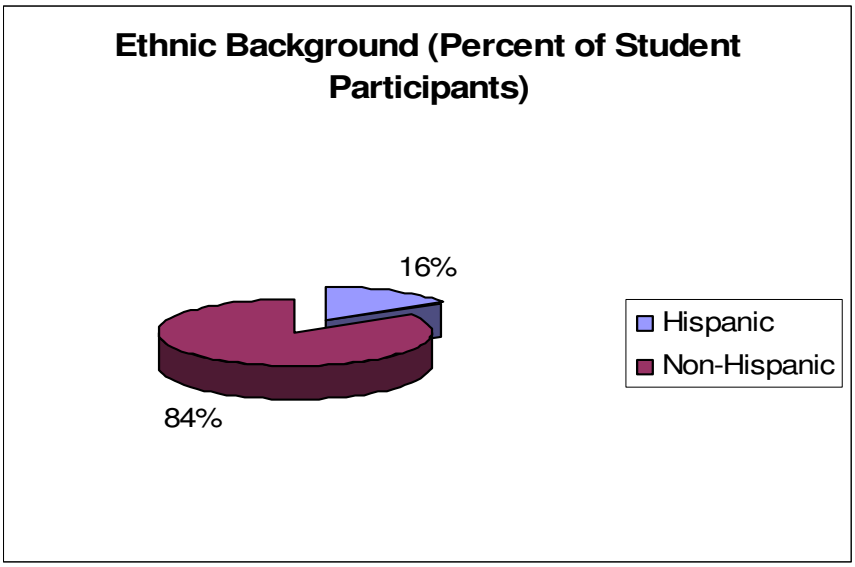

Figure 2. Ethnic Background of High School Participants in Fall 2007

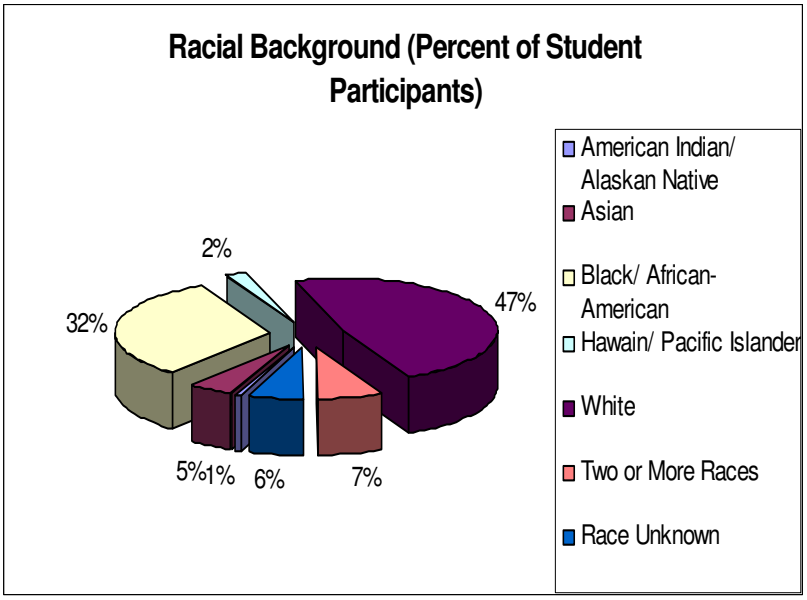

Figure 3. Racial Background of Participants

Evaluation Plan

Qualitative inquiry is an excellent approach to gain valuable information about people's experiences, perceptions, opinions, feelings, and knowledge[11] and is the approach taken for assessing the impact of the EPICS High model. As the implementation gains momentum, a series of ongoing assessments has been established and will be continually refined. To better accomplish our task we have broken our ongoing assessment into three (4) stages of evaluation that embody three (4) main questions.
Question (1) is to allow us a better understanding of what kind student is attracted to EPICS High, (2)what it means for a student to like EPICS High, (3)what is the impact that EPICS has on high school students, and (4) the re-evaluation stage, do we need to re-evaluate or adjust our questions/assessment during any of the former 3 stages.

Currently high schools are in their early stages of implementation. Consistent with initial stage (1) evaluation, students entering into these programs were asked questions that were concerned with their motivation or common interest for joining the program. These are the stage 1 survey questions:

Why did you join EPICS?
What do you want to do when you grow up?
What do you know about EPICS?
What do you expect to learn or gain from EPICS?
What are your views of engineers?

The initial results from the surveys included data from 3 schools with a total 80 responses. These schools are a representative of the three main types of schools found in our EPICS High program. There is one urban school populated heavily with underrepresented groups that consist of 30% women, one rural school with no women,

and one suburban school that consists of 70% women. Overall the demographics of 3 schools were 27.5% women (N=22 women) and 72.5% men, (N=58 men). In this population the ethnic identity as reported by the students were 28% white and 72% URM (underrepresented minority). When students were asked the above questions concerning the program some very interesting trends were detected and reported. When asked:

Question: why did you join EPICS:

75% women specifically stated that the reason they are joining was to help the community. The other 25% responded to this question and stated that the reasons that they got involved was due to their teacher' suggestion or that they were just curious to know what (the program) was about while only one response stated by females was that they wanted to know more about engineering. When men were asked this question, men gave substantially a more stratified response.

29% of men stated they were going into EPICS to help the community but men had many other reasons that they joined EPICS. The four major reasons, which was classified as a major reason was 10% or more was because it is a; class project 10%, it sounded interesting 10%, the teacher said to do it 20%. Another interesting point is that while we received answers to all other questions that were asked between men and women, 10% males decided not to answer this question which might suggests that this may be a question that is more important to women than it is men.

Question: what do you want to do when you grow up?

31% of total students say they want to be engineers but not because they want to help people.

14% of the women talked about wanting to become an engineer but only 1 made the connection that they can become an engineer to help people.

42% of the total students talked about helping the community. However only 1 woman and 1 man made a connection with going into engineering because they personally thought they could use engineering to help people in their community. This is interesting given that it is thought by engineers that engineering helps their community.

Question: What do you know about (the program)?

50%, half of the total students stated that they know that EPICS will help their community. The other 50% of students gave these two major responses- I don't know, and EPICS is an engineering design program. However, when we look at the percentage of the women response to this question, it is noticeably entrenched in helping their community

98% of all women stated that EPICS is about helping the community.

Question: What do they expect to learn or gain from EPICS?

When asked this question there were two main statements given. The first statement that was given was that students wanted 1) to learn how engineering lets me help the community. It is interesting to note that while this was made, this was the predominant statement that was produced by women. Here is a quote given by a female that is the summation of the majority female response to this question;

> "*When I am finished with the EPICS program, I hope to be able to look back at what I have done this year and gain a wonderful feeling from helping my community*."

The 2) second response given was to learn, get more knowledge and experience about engineering.

Question: What are your views of engineers?

When asked this question five main points where typically made from all of the students responses. They stated that engineers were intelligent, creative, problem solvers, successful, and that they build things. Other comments made on a lesser level; responsible, essential part or help society, and rich. In sharp contrast, 5% of the total population stated that their view of engineers is that engineers help the community or make a difference in the community. Out of the 5% only one (1) of the two (2) female participants actually thought that engineers have helped the community. This was the statement that was given by the second (2) female who mentioned community but still did not relate engineering with actually helping her community. She put helping the community in the context and with respect to building things such as bridges, roads, etc.

> *"Engineers are important to our country and help our community by building things like building roads, buildings, and bridges."*

It should also be noted, female (2) who made this statement did not want to be an engineer but rather wanted to be a professor because they wanted to teach young adults to further their lives or become a pharmacist to make people feel better.

Whichever way you look at the responses from the female and male population at most 5% may think that engineering helps their community. Some talked about society, "engineers help or are an essential part of society," but only in terms of something that seemed really not to be directly related to their community. It is interesting to note that only two females wanted to become an engineer out of the total surveyed population. One female wanted to become an architectural engineer because she wanted to design blueprints and the other female wanted to be an engineer to help her community.

Conclusion

The service-learning context appears to be drawing a significantly more diverse population than traditional approaches to pre-college engineering, both by gender and ethnicity. The concept of service-learning has the potential to add capacity to local communities as well as to schools through the work of the high school students working within the school district and thereby improving the pipeline coming to colleges. The program is also attracting students who do not necessarily see themselves as engineers.

This is particularly significant as it becomes an entry point into engineering in high school. Entry points into engineering, especially at the high school level are lacking. Initial evaluation of the students shows that they are interested for different reasons. The service-learning has the potential to bring students interested in making a difference into the engineering pipeline in larger numbers. It also has the ability to add capacity to the services in the communities and schools which will help the participating students as well as the other students and residents of their communities.

Many issues remain including issues of scaling of the program on a national level and sustainability of the pilot and subsequent school. More evaluation and assessment data will be gathered and analyzed as the program develops. The initial data is very encouraging and presents great promise. The project team is very encouraged from the initial success and looks forward to future studies on the impact of this model of early engineering.

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