Measuring the Impact of Service-Learning Projects in Engineering: High School Students’ Perspectives

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High School Students’ Reflections about Participation in Engineering Service Learning Projects (Work-in-Progress)

Introduction

There has been a constant call to increase the number of engineering graduates nationally to meet the demands of today’s workforce. To achieve this, there is a need to recruit more students into and retain them through college engineering programs. A great deal of effort has taken place over the last two decades to increase the overall number of students in engineering as well as addressing the issue of underrepresentation by gender and ethnicity within the engineering populations. While some progress has been made, the issues of underrepresentation remain with limited success nationally. As universities find ways to expose more students to engineering, engage a wider variety of students, and attempt to retain more students, they use innovative models for curriculum, pedagogy, and projects. Middle and high schools have historically faced challenges introducing engineering into the curriculum in an inclusive and authentic manner. Because these students are still flexible about their career decisions, programs that peak interest can still influence students’ college and career plans. An inclusive approach could have significant impact on the diversity of the engineering workforce.

A large public university implemented EPICS (Engineering Projects in Community Service) for undergraduates in 1995. The approach has been successful in preparing students professionally as well as addressing compelling needs locally and globally. The program has also shown that it is an inclusive approach to engineering that attracts populations that are traditionally underrepresented in engineering. Inclusive programs at the university can help retain students in engineering pathways but to impact students entering these pathways requires programming at the pre-college level. Motivated by the opportunity to begin EPICS in high school, three alums worked with a high school Biology teachers to pilot the concept. Their success motivated an expansion into an EPICS High program with support of a grant from the Learn and Serve America program in 2006 to open earlier inclusive pathways to engineering and provide students with experiences to inform their perceptions of engineering.

The initial pilot school simply took the university materials and used them with small adaptations to the high school teams. This was facilitated by three EPICS alums who were experienced in the program themselves. As the program sought to expand into schools without alumni mentors, a set of lesson plans were developed that teachers could adapt to use in their program. This approach was taken after focus groups of teachers and stakeholders were conducted. The result was a consistent theme that a flexible approach was desired and not a prescriptive curriculum. The national expansion begun in 2006 was done with this first version of the EPICS curriculum that reached more than 60 schools in 12 states.

The EPICS High maintains the same core values of the university program and uses service-learning to teach high school students design and expose them to engineering while benefiting
their local communities as they apply their knowledge and skills in authentic contexts. Each EPICS project is intended to be actually used by a recipient in the local community. Students are partners in the identification of the needs that they will address along with the teachers and community members. Student projects span all of the engineering disciplines and can be grouped into four broad areas: Education, Access and Abilities, Human Service, and Environment. The curriculum was designed as a flexible model that has been implemented as a dedicated class, part of a science or technology class, or as an after-school program. The curriculum helps guide students through the design process.

The initial data was encouraging and showed that EPICS could attract a more diverse student population that is traditionally drawn to engineering. The early cohorts were nearly gender-balanced with significant representation from Latino and African American students [reference ASEE 2008 and 2012 papers]. Student data showed that EPICS was having a positive impact on their view of STEM and engineering careers as shown in Figure 1.

![Program Ability to Motivate Students to Pursue a STEM Major](image)

In 2013, the EPICS program addressed feedback from teachers that a more complete curriculum was needed. The number of adopting schools had remained around 50-60 schools and the data showed that most teachers using the EPICS approach could be classified as early adopters and often had access to engineers or were engineers themselves. In order to offer EPICS to a broader set of schools, a more in-depth version of the curriculum was needed that followed the EPICS design process and values but was specifically adapted to a high school or middle school environment. This version of the curriculum was introduced in 2014 and is being used in part or fully in more than 100 schools from 16 states. EPICS remains a framework for designs that address a community need. Often the community partner for a high school is their school itself or a feeder school. These may involve partnerships with the special education teachers and
students, sustainability projects for the school or working with elementary teachers to design hands-on displays or materials for their students.

Evaluation has continued on the program both from a programmatic and student learning perspective. Data has shown that students in EPICS increased their interest in STEM careers but the question remained how much was attributable to the EPICS experience itself. An instrument based in Social Career Cognitive Theory was developed to assess change in self-efficacy, outcome expectations, and personal interest in engineering amongst high school students who participated in the EPICS High program. It was comprised of survey questions and open-ended responses. In addition to the focus on self-efficacy, outcome expectations, and interests, the survey addressed perceived attributes of an engineer, student understanding of scientists versus engineers, changes in grades, college and major goals, and contextual supports. More details about the full instrument have been published previously, and the analysis of the data is ongoing.

In the current analysis, we were interested in how participants characterized the impact of EPICS High in the pilot version. The open-ended questions from the survey allow us to investigate the impact of participation in the participants’ own words. These three questions also reveal the metacognition of students, begin to identify students’ expected outcomes, lay the foundation for comparison of student expressions of outcomes to the program’s outcomes, and identify factors that positively and negatively impact the program’s success. EPICS provides teacher professional development support, but we need to analyze the data from teachers and students to reveal alignment of outcomes and results. This paper presents the results from the analysis of two of the three open-ended questions from the instrument after pilot administration over 2 years across 11 states. The open-ended questions students answered were:

1. What are the three most valuable things you have learned from being a part of the EPICS program?
2. What are the things you enjoyed most about being a part of the EPICS program?
3. What are the three things you would change about the EPICS program?

For the scope of this paper, we present results from question 1 and question 3, analyzing what students learned and want changed.

Methods

Student surveys were administered during class or club time online through Qualtrics at the end of the 2013-2014 academic school year, resulting in 84 surveys. Data from the surveys were cleaned to remove incomplete entries and duplicates. After cleaning the data for duplicates and removing middle school student responses (School E), we de-identified and analyzed 73 completed responses. Student responses were analyzed using grounded theory to reveal popular themes and develop a codebook for analysis of future surveys. Because there responses were open-ended and the student surveys will be analyzed in the future, we chose not to use a priori codes and develop codes from the participants’ responses. Using grounded theory would also give us an opportunity to identify local themes within certain schools or classrooms.

The results presented are from four schools, whose descriptions are shown in Table 1.
Table 1. Descriptions of the EPICS High Pilot Schools

<table>
<thead>
<tr>
<th>School</th>
<th>Type</th>
<th>Program Style</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Urban, Private</td>
<td>Stand alone class</td>
<td>Southwest</td>
</tr>
<tr>
<td>B</td>
<td>Urban, Public</td>
<td>Stand alone class</td>
<td>Midwest</td>
</tr>
<tr>
<td>C</td>
<td>Suburban, Private</td>
<td>Afterschool</td>
<td>Midwest</td>
</tr>
<tr>
<td>D</td>
<td>Rural, Private</td>
<td>In Class</td>
<td>Midwest</td>
</tr>
</tbody>
</table>

Of the students who completed the survey, 65.8% were female and 34.2% were male. The high percentage of female respondents is due to the fact that two of the sites surveyed were all-girls schools. Table 2 shows the ethnicity demographics. It should be noted that students did report being American Indian or Alaska Native or Native Hawaiian or other Pacific Islander, but all students who reported that were also biracial or multiracial. Table 3 shows the distribution of the classifications of the students surveyed. Table 4 shows the first-time participants versus the repeat participants.

Table 2 Ethnic demographics of EPICS High Pilot Survey Participants

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>4%</td>
</tr>
<tr>
<td>Black/African-American</td>
<td>12%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>11%</td>
</tr>
<tr>
<td>White</td>
<td>55%</td>
</tr>
<tr>
<td>Biracial</td>
<td>12%</td>
</tr>
<tr>
<td>Multiracial (more than 2 races reported)</td>
<td>3%</td>
</tr>
<tr>
<td>Unreported</td>
<td>3%</td>
</tr>
</tbody>
</table>

Table 3 Classification of EPICS High Pilot Survey Participants

<table>
<thead>
<tr>
<th>Classification</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>15.1%</td>
</tr>
<tr>
<td>Sophomore</td>
<td>28.8%</td>
</tr>
<tr>
<td>Junior</td>
<td>21.9%</td>
</tr>
<tr>
<td>Senior</td>
<td>34.2%</td>
</tr>
</tbody>
</table>

Table 4 Tenure of EPICS High Pilot Survey Participants

<table>
<thead>
<tr>
<th>Tenure in EPICS</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>First time participant</td>
<td>57.5%</td>
</tr>
<tr>
<td>Repeat participant</td>
<td>42.5%</td>
</tr>
</tbody>
</table>

Results

What top three things did student learn from participating in EPICS?

Students identified more than twenty ideas or skills they recognized they learned. The most popular things students reported they learned were teamwork, helping people, problem-solving, community service, and the design process. The most popular responses are shown in Figure 2.
Students described learning how to work in teams, practice negotiating conflicts, and being flexible about sharing ideas. Students shared that “teamwork is mandatory” and that “you want to have a team with multiple backgrounds.” Students described learning the impact of problem solving on behalf of the improving society as a role of engineers (i.e., “Being an engineer you are committed to help people the community around you”), but students differentiated between the idea of helping people as an outcome and community service to their local community (i.e., “You have the opportunity to actually make a difference in your local community”). They mentioned the design process and multiple students used its major terminology in their responses. Daniel said, “I learned to create a persona for your project that you’re designing.” Jessie shared that she learned, “Identifying criteria and constraints.”

Though not the most frequent answers given when asked what students learned, students also reported that they learned many others specific things. Terms explicitly used included “patience,” “time management,” “responsibility,” “leadership,” “accountability,” and “discipline.” Some of these responses are included in the table below with a student response to provide an example in their words.
After reviewing what students revealed, we categorized their responses. As we characterized the student responses, we noticed that some of the responses spoke to concepts specific to the program and engineering, while others spoke to skills and personal individual characteristics that would extend beyond the program. This influenced the conceptualization of a hierarchy of student metacognition. The categories of things students learned are characteristics, skills, and concepts. Student responses are organized and shown in Figure 3.
Figure 3 Hierarchy of Student Metacognition Responses

What three things would you change about EPICS?

Students provided extensive feedback, and we ranked the responses to highlight the top five things they would change. Because of the amount of suggestions, certain items tied in popularity and resulted in thirteen suggestions as the top five changes. They were as follows: 1) more hands-on activities, 2) change or discontinue textbook, 3) more time in class or on projects, 4) learning about the engineering disciplines, 5) no changes, 6) changing the teacher, 7) changing the pace of the class, 8) changes to teaching structure and strategies, 9) advertising about the program, 10) class size, 11) more client interaction, 12) student autonomy to choose their own projects, and more visits from engineers to get ideas from the field. These suggested changes are shown in Figure 4.
Students identified things to change that fell into factors that related to program, school, classroom levels of implementation, and external factors influencing site implementation. For example, on the program level, EPICS has developed a curriculum that helps students walk through the engineering design process while meeting the needs of underserved members of the community. The teachers are trained to help them understand the process and help problem solve potential problems within their learning community. At the school level, funding for resources, classroom spaces, teaching assignments, and advertising of the class and student participation is determined by the partnership between teachers and administration. Finally, there are specific variables associated with the program such as location, scheduling, potential community partnerships and engineering mentorships are varied depending on the accessibility in the particular area. In the classroom, the teacher, pedagogical activities, physical space, and technology resources are key factors that impact student experiences. Figure 5 is a graphic concept map depicting relationships between student suggestions. This concept map depicts student suggestions as a program might view it, with program features such as curriculum being impacted by school and classroom factors. Factors such as EPICS interaction, funding and community involvement are considered factors beyond the school and classroom level that impact school and classroom experiences.
Discussion

After reviewing anecdotal evidence given from students about their EPICS experience, we can view its effectiveness in multiple ways. One process is to compare students’ metacognitive responses with those criteria that leaders in engineering and education have determined are necessary for a sustained and successful engineering workforce. We have pulled the following skills from the *Engineer of 2020*¹⁴: strong analytical skills, practical ingenuity, creativity, communication, business and management, leadership, high ethical standards, professionalism, dynamism, agility, resilience, flexibility, and lifelong learning. We can see from student responses that EPICS has impacted their practical ingenuity, creativity, communication, business and management, leadership, professionalism, resilience, and flexibility from the following student comments (and others previously listed):

- Practical ingenuity - “*draw from other disciplines,*” “*immense possibilities of creating*”
- Creativity - “*Innovation is key*”
- Communication – “*learning to listen*”
- Business and management - “*Perform some market research to make your product better*”
- Professionalism - “*Dress for success*”
- Resilience - “*if you put enough time into something, it will turn out great*”
- Flexibility – “*be open-minded*”

We would need more details about the projects and curriculum to investigate analytical skills, but this is beyond the scope of this particular paper. The other method is to compare student responses concerning what they learned to EPICS’ anticipated outcomes and learning objectives and their respective teachers’ objectives. These two comparisons are the next steps in future work.
The information students have given in regards to changing the EPICS program offers insight into what they expect from engineering projects and their perceptions about community involvement and impact (expected outcomes) as well as how these factors impact the program. Their suggestions also help identify successes and vulnerabilities of the program at various levels. Some of the suggested changes are counter to the premise of the program (such as individual student projects), but others were innovative and reflective. Students complained about the developmental appropriateness of the textbook used in the pilot, stating “they are not very modern and seem like they are for 6th graders”, and “it needs to be more user friendly” with “pictures” and “examples.” Students also complained about the pace of the curriculum and the time length of classes, both of which are subject to the implementation of the program at the school and classroom level. We see that the delivery of the curriculum and teacher preparation (as well as delivery and personality) have major positive and negative influence on the experience of students as it is mentioned across the three questions. Student comments about teachers included:

“I mean she’s great, but she has a reputation for being mean so not many kids her want to do engineering[.] There are literally 12 kids in my class.”

“The teacher made the class most unenjoyable.”

“...doesn’t do any engineering.”

We know that all teachers who participate in EPICS do not get trained in our curriculum, but we offer professional development opportunities to teachers. We understand that teachers who are engaging and have a personality that students resonate with are less likely to get negative feedback even if they are not well-prepared to deliver content, and we are confident that student experiences are also positively impacted because some students did report “interaction with a great teacher.” We are planning classroom observations and interviews to collect data that will inform the continuous revision of the curriculum and teacher professional development. We are also planning to conduct teacher and student interviews to document the local experiences of teachers and students. We will be conducting another survey to collect data after the implementation of the new curriculum to see how students respond to some of the changes.

**Implications for High School Engineering Programs**

Based on the students’ responses, we suggest recommendations for those creating curricula and high school programs. As expected, EPICS High pilot students wanted more hands-on activities, so we recommend others creating programs consider the inclusion of many hands-on activities or be cognizant of students’ expectations of them. Our interviews and classroom observations hope to define meaning of hands-on activities from the student perspective that will inform us and other curriculum developers. When developing the textbook or guide, design and layout should be developmentally appropriate and students did not like reliance on the textbook, so program developers should deliver content in an innovative manner. Students prefer adequate class time for project work, and might attend meetings before or after school to have more access to free time. Perhaps students could be allowed an EPICS study hall or laboratory option in their
schedule. Students want engagement with other communities doing similar projects. They wanted “more communication between groups working on similar projects.” They also wanted to interact with EPICS alumni who are “now living an engineering lifestyle.” We have not yet responded to either of these suggestions with program level changes or additions, but ideas are to host conferences so that students might be able to communicate and engage with each other and to build an EPICS community of current and past participants. Social media groups or online classrooms might also meet this student desire. Students want to learn about specific disciplines either through activities or by interaction with project partners or visiting engineers, so program developers should consider industry partnerships for a career day or generating profiles using media that can be archived online if visiting engineers are not easily accessible.

Since the development of this survey and the initial collection of the results, we have used the information from this survey and feedback from teachers to develop a pre-college curriculum based on the EPICS design cycle. We realize that students and teachers need guidance to develop a project that meets the needs of stakeholders while utilizing the engineering design cycle. Additionally, the curriculum needed to be aligned with NGSS (Next Generation Science Standards) along with the updated State and National Mathematics and English Language Arts standards that are embedded in the objectives. The updated curriculum is designed as an overarching structure that is fluid enough for the students to develop a project that is specific to the needs in their community, yet structured enough to give guidance to the process. This curriculum was designed for the overworked professionals in the educational setting to supply as many resources as possible to implement the EPICS program. The curriculum includes lesson plans, student sheets, along with videos and multimedia presentations to guide the instruction.

Because of the importance of reflective practice in engineering design, formative and summative assessments are included in the curriculum to help monitor student achievement and project success. Below you will find examples of these assessments:
The student survey data has provided important initial information concerning student learning related to service learning and the EPICS program, however there is more data to analyze other than the two open-ended questions studied. When we analyze what students say they like about EPICS, we can show relationships between what students learn, what students like, what they would like to change and the Social Cognitive Career Theory model that informed the survey. Yet, the fact that students want to share with the community and encourage their peers to explore engineering as a potential career path, gives us confidence that the original goals of EPICS are sustained and successful.

References


