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Impact of an Engineering Service Learning Program on Dual Credit High School Student Interests in Engineering (Evaluation)

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Abstract
Service Learning is a form of experiential education that allows students to apply knowledge learned in the classroom to solve a real community problem. This paper will examine the impact of an EPICS High service learning unit on the interests of high school students. The EPICS High unit is taught as part of a dual credit, introduction to engineering course offered by the University of Arizona. EPICS is a program that was developed at Purdue University to engage undergraduate students in real world engineering problems and to connect engineering with people and the local community needs. Today the EPICS program has been adapted for use in high school classrooms.

Data presented in this work were collected over three academic years. Participants were 406 high school juniors and seniors, 325 male and 81 female, who engaged in engineering service projects in their community as part of their ENGR 102 HS course. Data from all ENGR 102 HS students (n=1363) were also examined. Large numbers of participants came from groups typically underrepresented in engineering, including Hispanic students who make up forty percent of the sample. Results showed that EPICS High students who identified as Hispanic/Latino were more likely to express an interest in studying engineering than EPICS High students not identifying as such. Students who identified as Hispanic/Latino who participated in an EPICS high service learning project also showed a stronger interest in studying engineering in college than students of Hispanic/Latino ethnicity in an ENGR 102HS course without the service learning portion. Eighty percent of all the participants reported that participation in the EPICS High unit increased their interest in engineering and no significant gender differences were found. Participants also reported improved capabilities in the areas of teamwork, leadership and communication.

1. Introduction

According to the National Academy of Engineering (NAE) report, *Changing the Conversation*, educators need to rethink how engineering is portrayed to students and to the society as a whole. Young people today are very interested in helping others and in making a difference in the world. Because of this, the report advocates multiple and diverse pathways for students to come to engineering; pathways that are innovative, creative and that demonstrate the vast variety of career paths within the engineering profession [1]. EPICS, and service learning programs like it, have addressed this call and have been shown to attract a broad range of students, including young women and other underrepresented populations into the field of engineering. This is in part due to the way community service creates an authentic learning experience and naturally illustrates engineering as a helping profession [2], [3], [4], [5], [7], [8], [9]. As service learning programs develop and operate across the country, it is important to share best practices, establish teaching methods and to measure their success. In this paper one such program is evaluated, EPICS High, operated as part of the ENGR 102 HS program.

Now in its tenth year, ENGR 102 HS is a dual credit, introduction to engineering course offered by the University of Arizona (UA). Upon successful completion of the course, students who enroll in ENGR 102 HS receive three units of credit from the university. Each summer, the UA College of Engineering provides a four-day training to 35 or more high school teachers from around the Southwest so that they may offer the course to their students. During this workshop all ENGR 102 HS teachers receive training on EPICS High instructional methods and are offered various types of project support. EPICS High has been an elective unit in the ENGR 102 HS program for seven years and 10 to 15 high schools participate in service learning projects each academic year [10].

EPICS High seeks to motivate and equip middle and high school students in the areas of engineering, computing, and technology by engaging them in early engineering through the design, development, deployment, and support of community driven projects that meet relevant and real needs of their community. This service learning program reinforces STEM learning and teaches 21st century skills needed to succeed in tomorrow's workforce. Students develop useful skills as they work with community leaders to develop their designs. This model is aligned with research findings on diversity and has the potential significantly to impact the numbers and diversity of students coming into STEM pathways. Currently, Purdue University offers extensive summer workshops for middle/high school teachers who wish to operate the program in their school. Support is provided to over 100 middle and high schools in the United States and around the world.

Teachers who opt to offer an EPICS High unit as part of their ENGR 102 HS program are free to approach the EPICS curriculum as they see fit. Some teachers operate one classroom project for their whole group, and some do many. Some schools allow students to select their own projects in the community and many require students to stay on school grounds. Each school approaches the EPICS project time management in their own way. Some schools develop the community service projects at the end of the school year as a capstone while other schools operate long-term projects that students work on all school year and then continue to support in subsequent years. This wide-ranging teacher/student flexibility in project type, group size, and project management is important to the success of both programs.

Figure 1: In Spring 2014, students at Salpointe High School demonstrate the wheelchair swing they designed and built as part of the EPICS high program offered in their ENGR 102 HS course. Members of the community and local press look on.

The ENGR 102 HS program ran four pilot EPICS High programs in 2011, before there was even formal high school curriculum developed. Information collected from those school trials helped inform the EPICS adaptation for high schools. Today, between ten and fifteen ENGR 102 HS schools build EPICS High projects each year and the College of Engineering provides each school with $400- $500 for community service project materials. Over the past seven years student projects have included: a “tweeting otter” for the Tucson Desert Museum, a STEM learning trailer (operated by ENGR 102 HS students) that travels around to teach elementary school children, solar cell phone chargers for the high school campus and a secure swing for wheelchair patients (see figure 1). Additional projects include: the design and construction of a teachable-space greenhouse for the Peoria School District with a rainwater harvester and a living desert; a traveling harmonograph demonstration for the Tucson Children's Museum; a system for counting and recording the number of hikers on specific trails in Sabino Canyon State Park for the National Forest Service; and a lightweight hovercraft and wave table for the Physics Factory traveling STEM bus.

This evaluation focused on ENGR 102 HS students' responses concerning the impact of their EPICS High unit on their feelings about studying engineering in college. Also of interest was the Accreditation Board for Engineering and Technology (ABET) criterion three, dealing with engineering student outcomes; specifically we looked at the topics of teamwork, communication and project management [13]. Students were asked how participation the program impacted their skills in working as a team, written and verbal communication and project management abilities.

2. Framework: Service Learning and Experiential Learning Theory

2.1 Engineering Service Learning

Service learning is a form of experiential education that allows students to set learning goals, apply skills and techniques learned in the classroom and then to meet a need in the community. An important differentiation for service learning when compared to community service is the presence of a structured curriculum and the prominence of student/customer reciprocity and reflection [14]. For over 40 years educational researchers have studied and documented the overwhelming success of service learning programs in K-12 schools [10], [11], [12], [18] and in the university undergraduate environment [15], [16], [17], [19], [20], [21]. According to the National Center for Education Statistics (NCES), K-12 public schools offering formal service learning programs found it encouraged students to become more active members of the community, increased student knowledge and understanding of the community, met real community needs and encouraged student altruism and caring for others [22]. While involvement with the community is a key component of service learning, it is only a part of the service learning experience. The other side of service learning emphasizes the connection between service and academics. Schools also reported service learning fostered critical thinking and problem solving skills and improved student achievement in core academic courses [22]. This data on participation in service learning are grounded in long held educational theory. For most of the last century, John Dewey and other educational scholars have noted the advantages of "learning while doing," and the value of applying new knowledge into real work performed within the pupils' own community [23].

2.2 Experiential Learning Theory and the Engineering Design Process

Experiential Learning Theory (ELT) draws on the ideas of prominent 20th century scholars who focused on human experience when forming their theories about human learning and development [24]. Dewey's most basic model of learning focuses on observation of conditions, knowledge of what has happened before (or instruction on this), judgement of what should be done and finally action in the real world [23]. Kolb applies ideas from Dewey, Lewin, Piaget, Freire and others to form his Experiential Learning Theory. Kolb's ELT theory is based on six propositions [24], [25].

1. Learning is best conceived as a process.

2. All learning is relearning (or application of prior experience).
3. Learning requires the resolution of conflicts between dialectally opposed modes of adaptation to the world.
4. Learning is a holistic process of adaptation to the world. Includes thinking, feeling perceiving, and behaving.
5. Learning results from synergetic transactions between the person and the environment.
6. Learning is the process of creating knowledge (social knowledge is recreated in the personal knowledge of the learner).

It is not surprising that the act of building engineering projects lends itself nicely to the Experiential Learning approach when similarities between the models for Experiential Learning Theory and the Engineering Design Process (EDP) are considered. Critics of the ELT approach to education worry that learners become too disconnected from reality since it focuses on moving in and out of multiple modes of learning and this happens mostly within the learners head via; abstract hypothesis, active testing, concrete experience and reflective observation. However, in engineering service learning, students work to create real solutions for a real customer. While they might ride in and out of the iterative steps in the engineering design process, in the end their ideas must be resolved, not only with their engineering team members, but also with real people and situations in the world. In fact, it can be said that engineering service learning improves the effectiveness of ELT due to its necessary connection to the real world.

3. Methods

3.1 Participants

Data analysis for this paper will concentrate on selected questions from the ENGR 102 HS course evaluations collected for Academic Years (AY) 2014-15, 2015-16 and 2016-17. Two groupings of participants will be studied. Data from ENGR 102 HS students who participated in an EPICS High program (n=406) and then all the students in the ENGR 102 HS program (n= 1363) will be analyzed. All data come from high school juniors and seniors from 37 diverse Southwestern American high schools, across 15 school districts, and taught by 39 instructors. Detailed EPICS High results will examine female (n=81) and male (n=325) high school student responses. Racial and gender composition for the EPICS High treatment group is presented in Table 1.

Table 1. ENGR 102 HS / EPICS Participation Demographics by Gender and Race

	Female	Male	Total
Hispanic/Latino	35	129	164
American Indian/Alaska Native	2	1	3
Asian	10	23	33
Black/African American	3	5	8
White	30	153	183
Multi-Racial	1	10	11
Missing	0	4	4
Total	81	325	406

3.2 Instrument

At the end of the school year, ENGR 102 HS students fill out an online, 25 question course evaluation. The first four questions provide demographic data and the next 16 questions probe topics ranging from teacher effectiveness to satisfaction with the service learning program to college choice. Two additional questions are open-ended and allow students to describe their favorite ENGR 102 HS design and build project and comments about their teacher. The final four questions are for students who participated in the EPICS High program. The first specifically deals with the impact of the program on the change in students' likelihood of thinking about studying engineering (four point Likert scale: Less Likely, Neither More nor Less Likely, A little More Likely, A Lot More Likely.) Three additional questions assess improvement on skills in teamwork, communication and project management with a dichotomous, Has Improved/Has Not Improved response choice.

3.3 Results

Students participating in EPICS High service learning projects reflected very positively on their experiences. Overall, 80.3% of participants indicated that because of their EPICS participation they were a little or a lot more likely to think about studying engineering in college compared to the beginning of the year and only 6.4% suggested that they were less likely to do so. The number and percent of students endorsing each of the four-point Likert scale answer options is presented in Table 2. Mann Whitney U test revealed no sex differences on this question (Female Mdn=3; Male Mdn=3; U= 13058.5, p = .906 two-tailed). EPICS High students were classified into two groups reflecting underrepresent minority (URM) status. Students who identified as only White, only Asian or only Asian and White were classified as non-URM, all other racial combinations were included as URM. A Mann Whitney U test revealed a significant difference based on under-represented minority (URM) status such that students who are URMs (Mdn=3) were more likely to say EPICS High increased their thinking about studying engineering in college compared to students who are not URMs (Mdn=3) U= 19659.0, p = .005 two-tailed. Because students who identified as Hispanic/Latino were highly represented among EPICS participants, an additional test was run looking specifically at ethnicity. An independent sample t-test revealed that students who are Hispanic/Latino (Mdn= 3) were more likely to say EPICS High increased their thinking about studying engineering in college compared to students who were not Hispanic/Latino (Mdn=3) U= 17405.5, p = .018 two-tailed.

Table 2. Likelihood of EPICS participation leading to Thinking about Studying Engineering in College Compared to the Beginning of the Year

	Less Likely	Neither More nor Less Likely	A little More Likely	A Lot More Likely
Females	8/9.9%	8/9.9%	33/40.7%	32/39.5%
Males	18/5.5%	46/14.2%	133/40.9%	128/39.4%
URM	6/3.4%	14/8.0%	79/44.9%	77/43.8%
Non-URM	20/8.8%	39/17.2%	86/37.9%	82/36.1%
Hispanic/Latino	6/3.6%	14/8.5%	74/44.8%	71/43.0%
Non-Hispanic/Latino	20/8.3%	40/16.5%	93/38.4%	89/36.8%

Students were also asked if participation in EPICS High had improved their skills in working as a member of a team, skills in verbal and written communications and skills in managing projects compared to the beginning of the year. Mantel-Haenszel trends were conducted to see if any differences existed in endorsement of these questions based on gender, URM status, and ethnicity. No significant differences between groups were found. However, endorsement of these items was uniformly high for all groups as shown in Table 3.

Table 3. Improvement of Skills: Teamwork, Communication, Project Management

	Improved Skills Working on a Team		Improved Skills in Verbal and Written Communication		Improved Skills in Managing Projects	
	Yes	No	Yes	No	Yes	No
Females	75 (93.8%)	5 (6.2%)	67 (83.8%)	13 (16.2%)	73 (91.3%)	7 (8.7%)
Males	296 (91.6%)	27 (8.4%)	279 (86.4%)	44 (13.6%)	288 (88.9%)	36 (11.1%)
URM	163 (94.2%)	10 (5.8%)	151 (86.8%)	23 (13.2%	158 (90.3%)	17 (9.7%)
Non-URM	205 (90.3%)	22 (9.7%)	193 (85.4%)	33 (14.6%)	202 (89.0%)	25 (11.0%)
Hispanic/Latino	152 (93.8%)	10 (6.2%)	143 (87.2%)	21 (12.8%)	148 (90.2%)	16 (9.8%)
Non-Hispanic/Latino	220 (90.9%)	22 (9.1%)	204 (85.0%)	36 (15.0%)	214 (88.8%)	27 (11.2%)

A general question about the effect of participation in ENGR 102 HS on intention to become an engineer was asked of all students including those who did not participate in EPICS High service learning projects (N=1363). The number and percent of students endorsing each of the five-point Likert scale answer options are presented in Table 4. When compared to those who were not involved in EPICS High (Mdn=4) a Mann Whitney U test revealed that EPICS High participants (Mdn=4) were more likely to express an interest in studying engineering in college U= 255006.0, p = .009 two-tailed. When broken out by gender, the difference between EPICS participants (Mdn=4) and non-participants (Mdn= 4) remained significant for males U= 159948.0, p = .011 two-tailed but not for females. When broken out by URM status, the difference between EPICS participants (Mdn=4) and non-participants (Mdn=4) remained significant for students who are URMs U= 36770.5, p = .008 two-tailed but not for majority students. When broken out by ethnicity, the difference between EPICS participants (Mdn=4) and non-participants (Mdn=4) remained significant for students who identified as Hispanic/Latino U= 31645, p = .015 two-tailed.

Table 4. How Interest in Becoming an Engineer was Affected by ENGR 102 HS & EPICS						
	EPICS	Decreased Significantly	Decreased Somewhat	Did Not Change	Increased Somewhat	Increased Significantly
Females	Yes	2 / 2.5%	9 / 11.1%	16 / 19.8%	30 / 37.0%	24 / 29.6%
	No	8 / 2.8%	24 / 8.5%	73 / 26.0%	101 / 35.9%	75 / 26.7%
Males	Yes	1 / 0.3%	12 / 3.7%	68 / 20.9%	139 / 42.8%	105 / 32.3%
	No	25 / 2.3%	59 / 5.5%	258 / 23.9%	438 / 40.6%	299 / 27.7%
URM	Yes	1 / 0.6%	7 / 4.0%	29 / 16.5%	77 / 43.8%	62 / 35.2%
	No	14 / 1.4%	40 / 3.1%	104 / 16.6%	177 / 26.8%	144 / 16.7%
Non-URM	Yes	2 / 0.9%	14 / 6.2%	53 / 23.3%	91 / 40.1%	67 / 29.5%
	No	19 / 2.2%	42 / 4.8%	225 / 25.7%	362 / 41.4%	226 / 25.9%
Hispanic/ Latino	Yes	1 / 0.6%	7 / 4.2%	28 / 17.0%	71 / 43.0%	58 / 17.7%
	No	13 / 3.0%	35 / 8.0%	94 / 21.5%	166 / 38.0%	129 / 29.5%
Non-Hispanic/ Latino	Yes	2 / 0.8%	14 / 5.8%	56 / 23.1%	98 / 40.5%	72 / 29.8%
	No	20 / 2.2%	48 / 5.2%	239 / 25.8%	374 / 40.4%	244 / 26.4%

4. Discussion

Service learning programs like EPICS High continue to show strong benefits to student intention to study engineering. Given the changing demographics of the United States, it is important that these benefits are especially pronounced among students who are URM and those identifying as Hispanic/Latino without serving as a deterrent to groups more traditionally attracted to engineering. Outcomes on the Accreditation Board for Engineering and Technology (ABET) criterion three: elements of teamwork, communication, and project management showed uniformly high endorsement across all groups. The data suggest that EPICS High might strengthen its efforts to improve verbal and written communication skills as this area is the lowest of the three criterion across all groups. Overall, EPICS High service learning was associated with a greater intention to study engineering in college when compared to students in ENGR 102 HS who did not do service learning projects. This was especially true of males, students who are URM and students of Hispanic/Latino ethnicity as demonstrated by the significant differences on their Mann Whitney U comparisons.

The success of the service learning approach as an educational method to pique students' interest in Engineering is evident. Service learning introduces engineering to the population in a way that is authentic and relevant to students' lives while at the same time is broadly appealing. With plans to roll out an AP Engineering course in the next few years, curriculum developers should consider including a service learning unit. In fact, the addition of service learning experiences is a valuable addition to all introduction to engineering programs.

5. Conclusion

We add our results to the body of literature on the subject of engineering service learning. Participation in the ENGR 102 HS programs' EPICS High service learning activities, have been endorsed by students as improving their teamwork, leadership and communication as well as their interest in a career in engineering. Results from this evaluation support findings from decades of research on the topic of service learning [7], [8], [9], [10], [11], [12], [14], [15], [16],

[17], [18], [19], [20], [21]. Additionally, our data included large numbers of participants from groups typically underrepresented in engineering, including Hispanic students who make up 40% of the sample. EPICS High students who identify as Hispanic/Latino were more likely to express an interest in studying engineering than students who did not identify as Hispanic/Latino. They also showed a stronger interest in studying engineering in college than Hispanic/Latino students in ENGR 102 HS without the EPICS High service portion. The same pattern was found among the broader group of URM students such that EPICS High students from URM groups were more likely to express an interest in studying engineering than EPICS High students from majority groups. EPICS High students from URM groups also showed a stronger interest in studying engineering in college than students from URM groups in ENGR 102HS without the EPICS High service portion. These results support that ENGR 102 HS student participation in an EPICS High service learning unit is an effective tool for improving student interest in engineering.

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