International Journal of Engineering Education Vol. 34, No. 2(B), pp. 734–745, 2018
Printed in Great Britain

0949-149X/91 $3.00+0.00

Impact of the EPICS Model for Community-Engaged Learning and Design Education*

WILLIAM OAKES
School of Engineering Education and EPICS Program, Purdue University, 701 W. Stadium Ave., West Lafayette, IN, USA.
E-mail: oakes@purdue.edu

JAMES HUFF
Engineering and Physics Department, Harding University, 915 E. Market Ave., Searcy, AR, USA. E-mail: jlhuff@harding.edu

CARLA B. ZOLTOWSKI
School of Electrical and Computer Engineering, Purdue University, 465 Northwestern Ave., West Lafayette, IN, USA.
E-mail: cbz@purdue.edu

DEVENDRA CANCHI
Monitoring Analytics, 68 Kathryn Lane, Spring City, PA, USA. E-mail: Devendra.Canchi@monitoringanalytics.com

Design experiences offer opportunities for students to develop a wide range of technical and professional skills. Community-engagement or service-learning is becoming more pervasive in engineering and offers opportunities for students to engage in designs that address human, community and environmental needs. Connecting engineering with these areas is cited in the literature as a means to potentially enhance diversity and retention. Analyses in this paper indeed show a positive impact on the retention of students who engage in the EPICS Program early in their academic program and female students in particular. Furthermore, there are many benefits of extended design experiences and the data shows that participation over multiple semesters has a significant impact on the depth of the experiences. In addition to the personal benefits, the participation of students over multiple years also offers opportunities for mentoring younger students within the course and can further impact the diversity and retention efforts.

Keywords: service-learning; community engagement; retention; multidisciplinary design

1. Introduction

Design is a central element of the engineering profession and engineering education. In addition, design experiences provide opportunities to develop the broad attributes needed by the graduates of 2020 and beyond: professionals who are technically strong and also able to adapt to changing environmental, cultural and economic conditions [1, 2]. Furthermore, research in engineering and design education has depicted the rich complexity of teaching and learning engineering design. For example, such research would indicate an ‘‘informed’’ [3] student of design would be able to generate an expansive view of the ‘‘problem definition space’’ [4], respond to this problem space with a variety of initial design concepts [5], iterate between multiple phases of a design process [6, 3], coordinate the interests of multiple stakeholders in the design [7, 8], and employ an array of other strategies needed for effective design [3]. Though such research does highlight the complexity of design, it also emphasizes that the variety of concepts that undergird design must be learned if they are to be effectively enacted. How might such a broad range of design skills and cognitive strategies be learned? As we and others have earlier claimed [9, 10], relegating design education to a singular capstone experience, as is often implemented in engineering degree programs, seems to not fully cultivate such learning in engineering students. In contrast, we suggest that an extended experience in practicing real design would offer students the opportunity to engage in a more full range of design skills and thinking [9].

However, while design might be considered as a core practice of engineering [11], engineering in the workplace also involves a range of other skills, including effective communication [12], technical coordination [13], and teamwork and leadership skills [14]. How might engineering, then, be learned—not merely as a disciplinary body of knowledge—but as a way of being, where the associated skills become ingrained within the identity of the learner? [15]

Human-centered design approaches have gained traction within engineering education exposing students to the ideas of users and stakeholders being part of the design process or even design teams. These approaches have been shown to be most effective on student development when the design teams can interact with real users within an authentic context [7]. Additional challenges are introduced

* Accepted 12 January 2018.

when the projects are driven by an external customer with their own needs and timetables. However, a challenge facing many institutions and engineering educators is how to bring "real" design experiences into the curriculum that simulate many characteristics of professional practice, including opportunities to work on multidisciplinary and vertically-integrated teams for multiple semesters.

Although industry projects are a common approach to simulate the kind of environment that students will face after graduating, community-engaged learning or service-learning is a pedagogy that has gained more acceptance within engineering education. It offers opportunities to introduce design experiences that by their nature integrate human, cultural, environmental, and community issues into the design contexts. Design is the most common place where community-engagement is practiced within engineering education. There are a growing number of successful models of engineering-based community engagement in the U.S., Canada and globally in faith-based and secular institutions. These strategies have been characterized as Learning Through Service (LTS) [16] and use community engagement as a way to enhance the undergraduate experience [17]. Community-engagement or service-learning has been shown to provide many benefits related to academic performance, motivation, ability to work with others, leadership, overall satisfaction, aspiration for advanced degrees, and preparation for work [18–21]. In addition, these community engagement programs and service-learning courses have been posited as playing a significant role in the preparation of the core skills for practicing engineering. As Bielefeldt et al have claimed "[project-based learning] and [project-based service-learning] are both effective pedagogies to achieve a broad array of core knowledge and skills that are critical for engineers" [17, p. 542].

Studies have shown that community-engaged design experiences offer the kinds of experiences with real users that allow students to develop in the design skills and their understanding of the importance of user information and interaction in design. Situating the design work within community, human and environmental contexts aligns with three decades of research on diversity. Evidence from community-engaged programs show more diverse participation. Most EWB-USA chapters, for example, are nearly gender balanced [22]. This paper will examine two dimensions of impact on a design program that uses community partnerships for all of the design experiences that have not been previously investigated. First, the impact of participation in such a design program on retention. And second, the impact of participating over multiple semesters in such a program as opposed to one or two semesters.

1.1 Engineering projects in community service program (EPICS)

The Engineering Projects in Community Service Program (EPICS) began at Purdue University in 1995 [23]. The original goal was to provide an authentic design experience to prepare students for leadership in the global economy. The curricular structure of the EPICS courses was designed to allow students to participate multiple semesters or years, so they could experience multiple iterations of the design process. The authentic design experiences all addressed a local community need that generally fell into one of four categories: Access and Abilities, Education and Outreach, Environment and Sustainability and Human Services. In addition to providing benefits to the students, the curricular structure provided continuity to the community partners by sustaining the projects over multiple semesters. During the first semester, 40 senior-level Electrical and Computer Engineering (ECE) students participated. It rapidly grew in terms of numbers of students and projects as well as academic levels (sophomores, juniors and first-year students) as well as becoming very multidisciplinary [24]. Figure 1 shows the enrollment trends over the last ten years including the total enrollment and the number of returning students each semester. The returning students provide continuity and allow projects to span multiple semesters giving students to experience multiple iteration cycles of the design process and to provide the time where they can take on multiple roles within the design teams. It also provides the community with a long-term partnership that allows projects of significant scope and impact to be completed rather than only one semester or one year projects. The long-term partnership also provides a network that addresses field failures and maintenance of delivered designs. Over the last eight years EPICS has average 45 majors participating and drawing students from every college of the university. 80% of the students are from engineering on average. The EPICS has been disseminated to other universities and colleges with 35 programs currently active with EPICS courses at their own institutions.

Community-engagement shares the characteritistics cited in the diversity literature and the EPICS program has seen a student population that is more diverse than the overall population from the college. An example is the percentages of Electrical and Mechanical Engineering students who are female in EPICS as shown in Fig. 2 [18]. The EPICS Learning Community consisted of First-Year Engineering students who were are able to use EPICS for

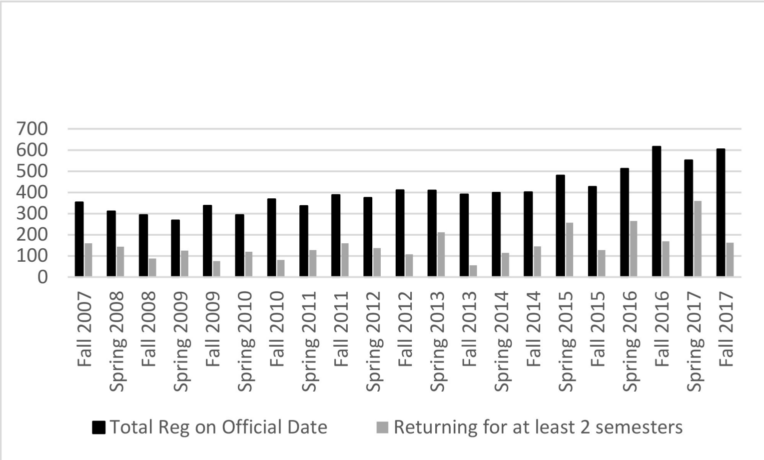

Fig. 1. Enrollment in EPICS, Total Number and Returning Students.

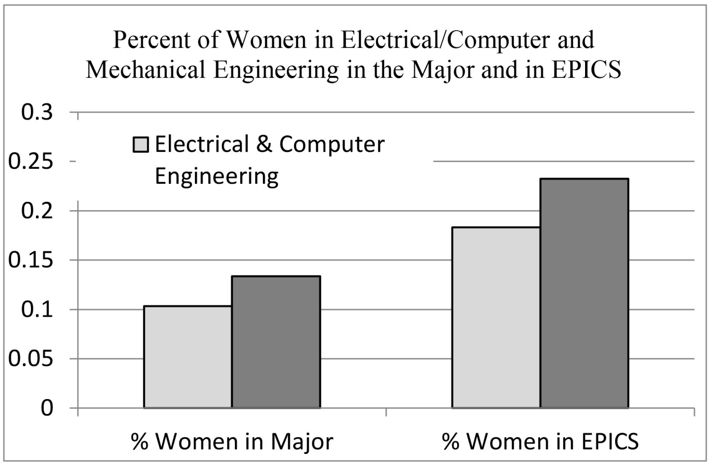

Fig. 2. Distribution of Women in EPICS from Mechanical and Electrical and Computer Engineering [18].

their first engineering course. From 2014–2016, the 120 person Learning Community cohorts who chose this option was 44% female compared to 25% in the overall engineering population. Data shown in Fig. 3 indicates that the women were drawn to EPICS by the ability to gain authentic engineering experience and that it was connected to the community and making a difference in the lives of others [25]. The male respondents showed similar trends but the women showed a strong connection with the design experience and the community impact. These findings were similar to an analysis of interviews from women in EPICS on why they chose EPICS [18].

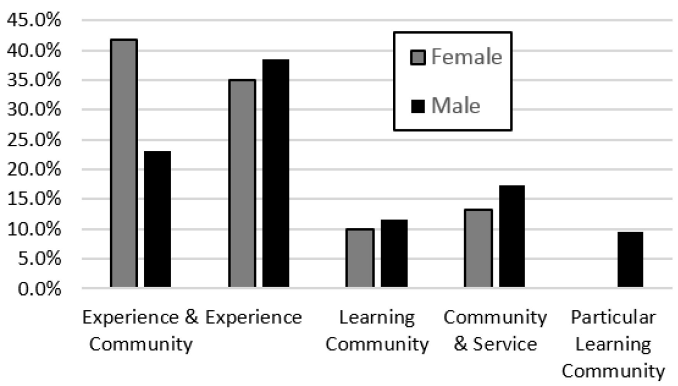

Fig. 3. Why Students Chose EPICS in their First Year [13].

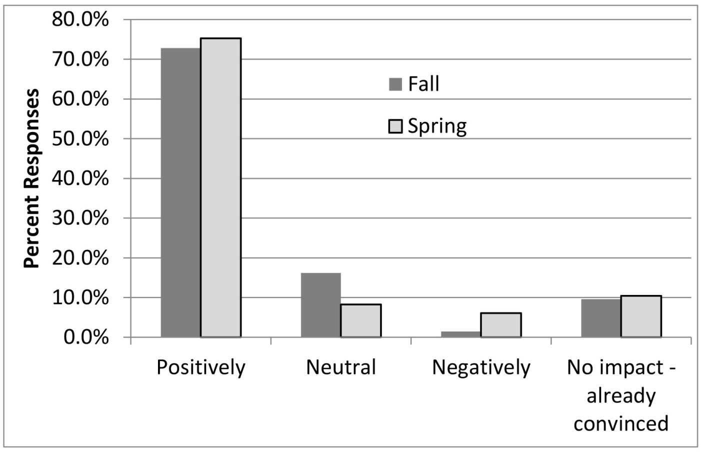

Fig. 4. Impact of EPICS on Motivation.

A version of EPICS has also been adopted by 73 high schools and middle schools. This program's incorporation in these schools has shown an impact on diversity of interest in engineering with a student population that is 56% female and 61% minority.

Data have consistently shown that programs such as EPICS attract a population more diverse that the general engineering population. Much less has been written about the impact of such programs on student retention as well as the impact of participation over multiple semesters. Therefore, this paper will report on our findings for the following two research questions:

RQ1: Does participation in EPICS affect a student's graduation rate in engineering or computer science?

RQ2: Is there a relationship between semesters of participation in EPICS and how students develop in their learning?

The following sections detail two studies to answer these research questions.

2. Study 1: EPICS and graduation rates and retention

Previous research has suggested that EPICS would have a positive impact on student retention. Community engagement and service-learning have been studied and there are many studies that show a positive impact across many disciplines [26–35]. Most of these investigations studied placement-based engagement where students spend certain number of hours in service or embedded within a community or agency. Design-based engagement is project-based where the value add to the community partner is primarily the design work. Some studies have shown that engineering design-based engagement can benefit retention. M. Lima reported that after taking a Biological Engineering Service-Learning class at Louisiana State University, 93% of Women and Minority students remained in their discipline compared to the national average of 70% [36]. A similar result was found for students in a multidisciplinary service-learning course. Piket-May and Avery also reported retention gains more than 6% for students who participated in service-learning in their first-year [37].

One strategy to understand the influence of the EPICS on student retention was through an analysis of self-report data. In final course evaluations, students were asked "What impact has the EPICS Program had on your resolve to continue in your major?" The results showed a strong and positive response. This data was collected anonymously with N = 136 in the Fall, and N = 182 in the Spring and is shown in Fig. 4. The following year later, similar data was collected with identifying information to determine the gender of the respondents with N=238 in the Fall and N = 201 in the Spring and shown in Fig. 5. The questions were worded slightly differently asking them to "Check the response that best reflects the impact that EPICS has had on your resolve to continue in your major."

- The EPICS program has had a positive impact on my resolve to continue in my major.
- The EPICS program has not had much impact because I was already very committed to my major.
- The EPICS program has not had much impact on my resolve to continue in my major.
- The EPICS program has had a negative impact on my resolve to continue in my major.

These results showed a strong positive self-reported increase in motivation among both men and women. The number of students who reported no influence increased with the largest indicated that

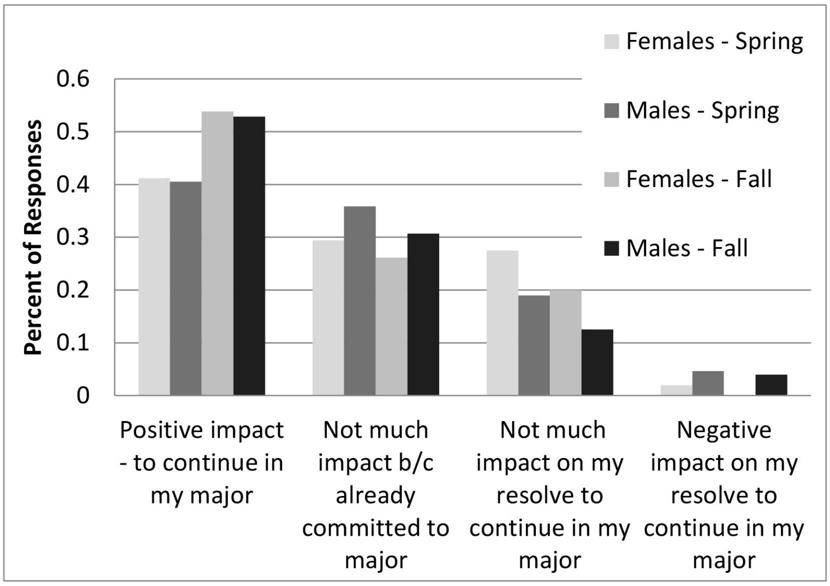

Fig. 5. EPICS Impact on Motivation.

they were so dedicated to their major that it wouldn't have an impact. Like the previous year, few reported a negative impact.

2.1 Methods

The self-report data indicated a positive impact on persistence, but a formal retention investigation was undertaken to ascertain if there is an influence on persistence. The data for this study was obtained from the University-Student Decision Support System (DSS). The information collected by various departments within the University during a student's tenure is organized and stored in this database. The following three sets of data were used to complete the study.

(a) The information that defines a student's profile such as the beginning academic year and semester, gender, ethnicity, standardized test scores etc., which are collected at the time of a student's admission by the Office of Enrollment Management.
(b) The information related to a student's progress such as classes registered, grades obtained, declared major and minor are collected periodically—at least twice a semester.
(c) The information on degrees awarded to a student, which is provided by the Office of the Registrar.

For the purpose of the present study, a student was considered retained if he or she graduated from an engineering or computer science discipline within six years from the date of first enrollment. The students who have graduated within the first six years of their enrollment are grouped as *retained* and those who have not are grouped as *not retained*. Those students who had not graduated but yet to cross the six year window are grouped as *yet to complete*. Among those *yet to complete* students, students registered with any one of engineering schools or computer science as of semester analyzed are grouped as *on track to retention* and those registered with schools outside engineering or computer science are grouped as *not on track to retention*. The data pertaining to *on track to retention* characterizes the latest information that was available on student's behavior. This method captured all students in each cohort who have not graduated as either *on track* or *not on track* in engineering or computer science. We considered this as a reasonable precursor to the future retention behavior. The rate of retention for a group of students is simply the ratio of students who have been retained to the total number of students.

A student's retention behavior was likely to be affected by several factors such as their background and their immediate educational and social environment. To isolate the effect of participation in EPICS program on the retention behavior, we needed to control for all the known measurable influences except for their revealed choice of taking an EPICS course. Our study progressed by comparing the retention behavior of students who have taken EPICS courses with a reference cohort who share the following listed characteristics with the former group but have not participated in the EPICS program.

1. *Academic Year and Semester*: The first time a student takes an EPICS course defines this group. For example, all students who have

Table 1. Students Analyzed for Retention Study

Not Retained		Retained		Yet to Complete	
EPICS	**ENG CS**	**EPICS**	**ENG CS**	**EPICS**	**ENG CS**
288	24,901	1,564	89,331	442	32,812

Table 2. Retention Rates

Retention Rate				Significance		
EPICS	**95% CI**	**ENG CS**	**95% CI**	**Diff.**	**95% CI**	**p-Value**
84.4%	[83% –86%]	78.2%	[78%–78%]	6.2%	[5%, 8%]	0.0000

taken an EPICS course for the first time in the Fall, 2001 are compared to only those who are enrolled in the Fall, 2001 within Engineering and Computer Science disciplines. This controls for any curriculum changes and differences in University's policies over time.

2. *Student's Semester*: The student's progress in the program is a major indicator of his or her retention behavior. For example, the group of students who has taken an EPICS course for the first time during their Junior-first semester is compared against only Junior-first semester students within Engineering and Computer Science.

In brief, a cohort of Junior—first semester Engineering and Computer Science students who have taken an EPICS course for the first time are compared against Engineering and Computer Science students who are in their Junior—first semester during same semester and have not taken any EPICS courses up until that time. Tables 1 and 2 show the numbers of students involved in the study and the overall retention rates respectively.

2.2 Results

The data show that the retention rates are statistically significantly higher for students who participate in their first two years. Figure 6 illustrates this finding by graphically breaking out the retention rates by years with the rate as a diamond and the 95% confidence band as a grey shaded banded. Early participation in the community-based design shows a higher rate of persistence. This is consistent with the placement based studies in other disciplines and previous studies in engineering. The data are positive or neutral throughout the years of study with the exception of the second semester of the senior or final year. N = 5 overall for these students provides a small data set that included students taking EPICS to fill a schedule as they attempted to raise their GPA to meet engineering graduation requirements. While it could bear further investigation these data are hypothesized to be a function of the small N. There was no indication in the data that students in the final year were turned away from graduating in engineering or computer science by their EPICS experience.

The data is also broken out by gender to explore the impact on female students and is shown in Fig. 7. While the retention rates are higher for the EPICS students, they are not statistically significant due to the lower number of participants. There is a similar phenomenon as in Fig. 6 in the final semester. Figure 8 shows the data for the female students and includes the "on track" students in

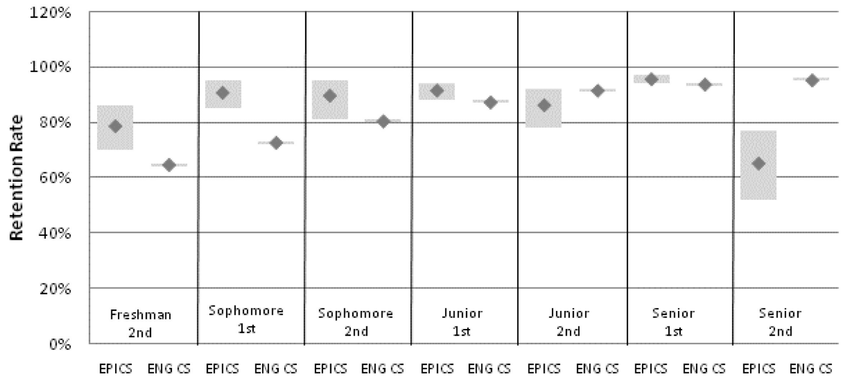

Fig. 6. Overall Retention by Academic Year.

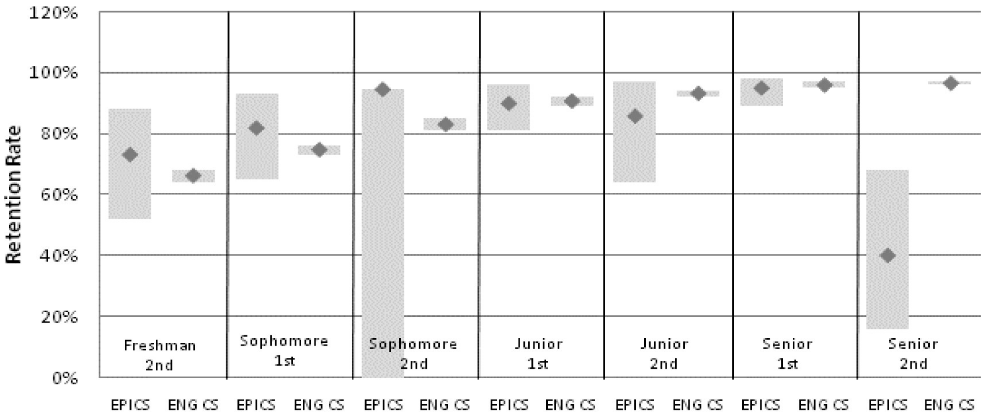

Fig. 7. Retention Rates for Females by Academic Year.

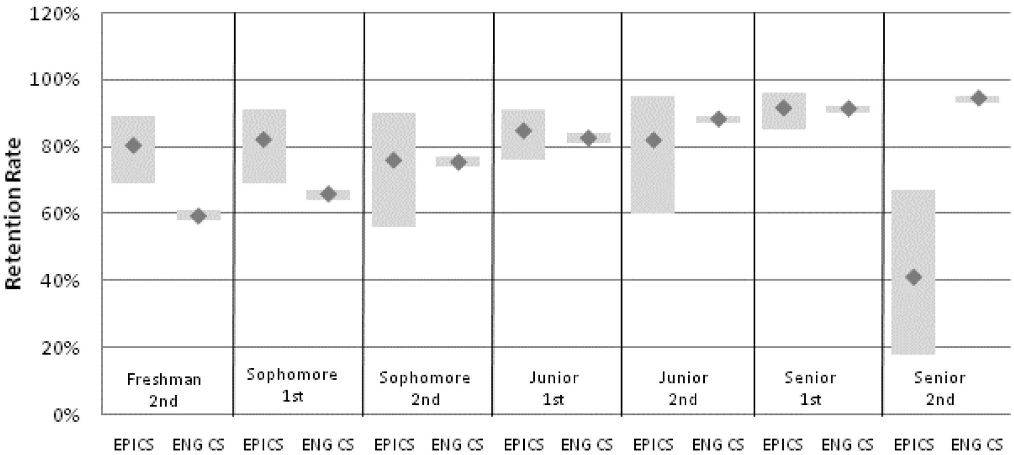

Fig. 8. On-track Retention Rates for Females.

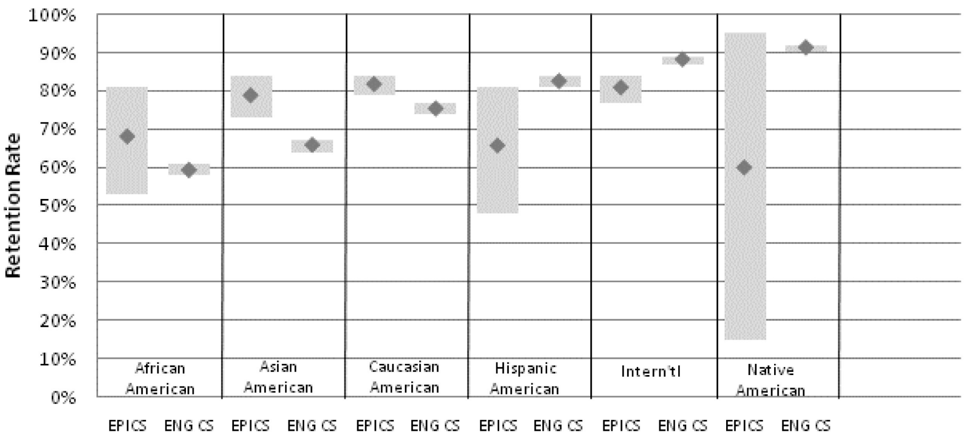

Fig. 9. Retention by Ethnicity and Academic Year.

the analysis. When the students who are still in the majors and "on track", the retention gains for EPICS become significant in the first two years of their academic program. A similar analysis was conducted sorting students by ethnicity. Figure 9 shows that there are retention gains for the EPICS African American, Asian American and Caucasian students, although the African American do not fall outside of the 95% confidence bands. The retention is lower for Hispanic, and Native American but they are not statistically significant. International students were found to be statistically lower. Further studies are planned to further explore the retention impacts.

3. Study 2: multiple semester participation

The data used in the present study was collected for a larger study that was conducted with the goal of assessing the effectiveness of EPICS on students after they graduated [38]. In this larger study, we collected survey responses from alums of EPICS (n = 523) and conducted in-depth interviews with a smaller, purposefully sampled set of alums (n = 27). This study of EPICS alumni showed that the engineering students used the community-engaged design experiences in their careers in industry [39]. The contexts of the design were different, but they transferred the knowledge, experience and skills they developed in EPICS to address the challenge after entering the workforce. The authentic design experience prepared them for leadership in engineering and design careers. In-depth interviews were conducted following the surveys from a purposefully sampled population of survey respondents. They identified areas of impact of the program on their careers in traditional industries. Details on the survey and interview process is found in [38, 40].

The alumni data contained participants who took EPICS for a range of semesters and the present investigation studies how this extended participation affected how they perceived the outcomes of the course. It is an elective and therefore up to the students how long they enrolled in the course. Informed by prior literature, we would expect that through prolonged engagement in such a course, a student would substantially enrich his or her development as a professional, and especially, as a person. In other words, enrolling in EPICS for multiple semesters would facilitate an extended learning experience rather than a duplicated learning experience. While we have not found any prior literature that would directly inform our position on such prolonged engagement in service-learning design courses, we might reasonably posit such a claim through examining relevant theory from engineering education, situated cognition, and allied fields.

3.1 Methods

In order to determine the effect of multiple semesters in EPICS while controlling for the effects of other variables, a multiple regression analysis on the survey responses was conducted. The survey administered to the alums collected demographic variables and information about the students' academic career (e.g., major, graduation year, and number of semesters in EPICS). Further, we gathered data from 27 items that examined the perceived influence of EPICS on a variety of abilities and attitudes related to engineering work and community engagement. As we have discussed elsewhere [38], the results depicted that EPICS did indeed have a substantial effect on many alums after they received their bachelor degrees. For example, of those 27 items, over 80% of survey respondents indicated that EPICS had, at least, contributed to "some extent" on their development of several professional competencies and attitudes, (e.g., their abilities to function and lead in a team environment, their abilities to effectively communicate effectively, and their appreciations for engineering as a profession that benefits society; see [38]). For other similar items related to workplace competence, respondents indicated that EPICS bore a strong influence on these abilities and attitudes. Fewer respondents indicated that EPICS played a prominent role in cultivating a desire to engage their communities. However, even in these items related to community engagement, over half of the respondents indicated that EPICS had contributed at least "some extent" to cultivating such a desire for community engagement.

3.2 Results—multiple regression analysis

In order to determine the effects of multiple semesters of experience in EPICS, we conducted a hierarchical, multiple regression analysis. As described by [41], this method is an effective way of exploring the effect of one variable on a dependent variable, while controlling for the effects of other variables. In other words, multiple regression analysis provides a way of exploring the unique contribution of a certain independent variable (e.g., number of semesters) to a dependent variable even when other variables (e.g., demographics, major, and year of graduation) are taken into account. The contribution to a dependent variable is understood by the amount of variance accounted for by the independent variables of a model relating these variables to a dependent variable. We began by describing the independent variables used in our model and as well as the dependent variables.

Independent Variables:

We considered the gender of the respondent as an independent variable within our model. We named this Boolean variable *Female* as the value of the variable was "1" if the participant was female and "0" if the participant was male. As shown in Table 3, over 98% of survey respondents indicated their gender.

We also considered *Race/Ethnicity* as a categorical variable, which initially spanned eight categories of races and ethnicities. Because of the small representation of participants in six of these categories, we reduced the categories of race/ethnicities to encompass three categories— *Asian*, *White*, and *Other or Multiple Races/Ethnicities*—all of which had over 30 participants. Further, as shown in Table 3, approximately 87% of survey respondents reported their race/ethnicity.

Engineering Major was a Boolean variable that was coded as "1" if the participant reported graduating from the College of Engineering and "0" otherwise. All participants reported their major associated with their bachelor degrees. As seen in Table 3, the participants were largely engineering graduates.

We considered *Graduation Year* as a categorical variable that spanned four categories of possible graduation years. The categories each reflected a range of four or five years, beginning from the time of EPICS inception (1995) and ending the year prior to the data collection (2011). As seen in Table 3, the range of participants slightly skewed toward more recent graduates. However, as seen in our previous work [38], such a skew is reflective of the number of participants that actually graduated from EPICS in these years.

Finally, the variable of interest to this investigation, *Number of Semesters in EPICS*, indicated the number of semesters that a respondent participated in EPICS. Participants self-reported this item, and the largest option they could select was 5 or more semesters. As seen in Table 3, at least 59 participants selected each option from this ordinal variable.

Dependent Variables:

As indicated earlier, the dependent variables reflected the factors that resulted from the exploratory factor analysis of the 27 survey items which probed the effect of EPICS on professional and personal development from the 523 survey respondents. These factors were named EPICS Influence on (1) Professional Competency, (2) Perspectives of Engineering, and (3) Community Engagement. They represented the *mean of all valid responses* for items that loaded to the given factor. The possible responses for each item, which asked how EPICS contributed to a certain characteristic, was: "Not at all", "Small Extent", "Some Extent", "Large Extent" and "Very Large Extent." Survey respondents were given the option to indicate that an item was "Not Applicable", which rendered the particular item invalid for analysis. However, over 90% of respondents provided valid responses for each item. Moreover, each of the three dependent variables contained valid means for a large number of items.

3.3 Hierarchical multiple regression analysis

The results of the analysis are shown on Table 4. In the first step, we included *Female*, *Engineering Major*, *White*, *Other or Multiple Races/Ethnicities*, *Graduation Year: 1995–99*, *Graduation Year: 2000–03*, and *Graduation Year: 2004–07*. As described [41], the standardized regression coefficients from the dummy-coded variables (race/ethnicity and graduation year) tell the effect size of that specific

Table 3. Valid responses for independent variables

		Valid Responses (Total: n = 523)	
Independent Variable Name	**Independent Variable Categories**	**#**	**%**
Female	Male	369	70.6%
	Female	146	27.9%
Engineering Major	Engineering	427	81.6%
	Non-Engineering	96	18.4%
Race/Ethnicity	Asian	100	19.1%
	White	368	60.9%
	Other or Multiple Races/Ethnicities	36	6.9%
	• African-American/Black	11	2.1%
	• Hispanic	4	0.8%
	• Native American/Alaska Native	1	0.2%
	• Native Hawaiian/Pacific Islander	2	0.4%
	• Other	9	1.7%
	• More than One Race/Ethnicity	9	1.7%
Graduation Year	1995–1999	69	13.2%
	2000–2003	121	23.1%
	2004–2007	182	34.8%
	2008–2011	151	28.9%
Semesters in EPICS	1 semester	118	22.6%
	2 semesters	186	35.6%
	3 semesters	84	16.1%
	4 semesters	76	14.5%
	5 or more semesters	59	11.3%

category *with respect* to the category left out of the model. In other words, races/ethnicities included in the model (*White*, *Other or Multiple Races/Ethnicities*) are analyzed with their effect when compared to the *Asian* category. Additionally, graduation years are all compared to the *Graduation Year: 2008–11* category. The decision to include and exclude this particular set of dummy-coded variables was informed by examining the full range of comparisons of the race/ethnicity and graduation year categories. Table 4 demonstrates that there was a significant difference between participants that identified as *Other or Multiple Races/Ethnicities* in relation to participants that identified as *Asian* on responses of items related to *Community Engagement*. Additionally, the table highlights prominent difference between *White* and *Asian* categories across all the dependent variables. In contrast, there was no significant difference between participants that identified as *White* in relation to participants that identified as *Other or Multiple Races/Ethnicities*. However, as we later elaborate, we caution against drawing strong conclusions based on the *Race/Ethnicity* variable.

Additionally, the salient comparison among the graduation years was between graduates in the years *1995–99* and *2008–11*. As can be seen on Table 4, there is a significant difference on responses to items related to *Community Engagement* and *Perspectives of Engineering* between respondents that graduated in *1995–99* in relation to those respondents that graduated in *2008–11*. We checked other comparisons among graduation years, but there were not significant differences in effects among the remaining categories of *Graduation Year*.

As can be seen in the first step of the multiple regression analysis, the initial set of independent variables does not strongly predict the variance found in any dependent variable. This is especially the case for *Professional Competency* and less so for *Perspectives of Engineering*, and *Community Engagement*.

However, when we add *Number of Semesters in EPICS* to the model in Step 2, the variance accounted for by the model increases for each dependent variable. This increase is especially striking for *Professional Competency*, where the variance jumps from nearly 1% in the first step to nearly 16% in the second step! The increase in predicted variance is less prominent for *Perspectives of Engineering* (+5.9%) and *Community Engagement* (+2.5%), but the effect size of the multiple semesters of participation is still significant ($p < 0.001$) for all dependent variables. This robust result, then, tells us that even when a number of other variables are considered, the number of semesters that students were enrolled in EPICS bears a significant effect on the influence of EPICS in multiple dimensions related to professional competencies, perspectives of engineering, and community engagement.

4. Conclusions

Community-based learning is becoming more pervasive in engineering. Design-based community engagement offers many opportunities to impact

Table 4. Standardized Effects (Regression Coefficients) of Independent Variables on the Influence of EPICS on Professional Competency, Perspectives of Engineering, and Community Engagement

Step 1	**Professional Competency**	**Perspectives of Engineering**	**Community Engagement**
Female	0.05	0.12**	0.10*
Engineering Degree	0.03	0.12**	0.06
White	–0.13*	–0.09⁺	–0.22***
Other or Multiple Race and Ethnicity	–0.06	–0.01	–0.11*
Graduation Year: 1995–1999	–0.06	–0.14**	–0.11*
Graduation Year: 2000–2003	–0.01	–0.06	–0.02
Graduation Year: 2004–2007	–0.07	–0.08	–0.05
Variance Predicted (R^2)[1]	0.7%	3.4%	4.9%
Step 2	**Professional Competency**	**Perspectives of Engineering**	**Community Engagement**
Female	0.06	0.13**	0.10*
Engineering Degree	0.04	0.12**	0.06
White	–0.14**	–0.10*	–0.23***
Other or Multiple Race and Ethnicity	–0.04	0.01	–0.10⁺
Graduation Year: 1995–1999	–0.08	–0.15**	–0.11*
Graduation Year: 2000–2003	–0.03	–0.07	–0.03
Graduation Year: 2004–2007	–0.07	–0.08	–0.05
Number of Semesters in EPICS	0.39***	0.24***	0.17***
Variance Predicted (R^2)[1]	15.8%	9.3%	7.4%

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
[1] Total variance is given as adjusted R^2.

student experiences and learning. The pedagogy of community-based design is consistent with other literature, as well as data from many programs points to the potential to increase diversity and retention. Our analyses show a positive impact of EPICS on the retention of students who engage early in their academic program and female students in particular, aligning with prior literature and research. There are opportunities to explore this phenomenon further and with higher number of participants given the higher participation rate of first-year and sophomores in the program more recently.

Earlier studies documented the impact of the EPICS experiences on engineering alumni. While the community contexts differed from their industry experiences, they were able to transfer these experiences into the new contexts. Furthermore, there are many benefits of extended design experiences and the data from the EPICS program shows that participation over multiple semesters has a significant impact on the depth of the experiences. In addition to the personal benefits, the participation of students over multiple years also offers opportunities for mentoring younger students within the course and can further impact the diversity and retention efforts.

Community-based design experiences offer many benefits academically [21] as well as areas of diversity [18]. Data from EPICS alumni clearly shows that the design learning is at least similar to traditional academic design challenges and industry projects [38]. Additionally, the results of the design work impact our fellow citizens and the world we live in. The EPICS program, for example, had 147 active projects in 2016-17 that are calculated to impact 83,111 directly and 447,983 indirectly. We have opportunities to create powerful design experiences and leave the world a better place in the process.

References

1. National Academy of Engineering (2004), The Engineer of 2020: Visions of Engineering in the New Century. Washington, DC: The National Academies Press, (2005).
2. National Academy of Engineering, Educating the Engineer of 2020: Adapting Engineering Education to the New Century. Washington, DC: The National Academies Press, (2005).
3. D. P. Crismond and R. S. Adams, The informed design teaching and learning matrix, *Journal of Engineering Education*, **101**(4), 2012, pp. 738–797
4. R. S. Adams, J. Turns and C. J. Atman, Educating effective engineering designers: The role of reflective practice, *Design Studies*, **24**(3), 2003, pp. 275–294.
5. S. R. Daly, S. Yilmaz, J. L. Christian, C. M. Seifert and R. Gonzalez, Design heuristics in engineering concept generation, *Journal of Engineering Education*, **101**(4), 2012, pp. 601–629.
6. C. J. Atman, J. R. Chimka, K. M. Bursic and H. L. Nachtmann, A comparison of freshman and senior engineering design processes, *Design Studies*, **20**(2), 1999, pp. 131–152.
7. C. Zoltowski, W. Oakes and M. Cardella, Students' Ways of Experiencing Human-Centered Design, *Journal of Engineering Education*, **101**(1), January 2012, pp. 28–59
8. L. L. Bucciarelli, *Designing Engineers*, Cambridge, MA: MIT Press, 1994
9. J. Huff, C. B. Zoltowski, W. C. Oakes and R. Adams, Making sense of design: A thematic analysis of alumni perspectives, *Proceedings of the 2013 American Society for Engineering Education Annual Conference*, Atlanta, GA, June 2013.
10. S. Sheppard, K. Macatangay, A. Colby and W. Sullivan, *Educating engineers: Designing for the future of the Field*, San Francisco, CA: Jossey-Bass, 2008
11. C. L. Dym, A. M. Agogino, E. Ozgur, D. D. Frey and L. J. Leifer, Engineering design thinking, teaching, and learning, *Journal of Engineering Education*, **94**(1), 2005, pp. 103–120.
12. M. C. Paretti, Teaching Communication in Capstone Design: The Role of the Instructor in Situated Learning, *Journal of Engineering Education*, **97**(4), 2008, pp. 491–503.
13. J. Trevelyan, Technical Coordination in Engineering Practice. *Journal of Engineering Education*, **96**(3), 2007, pp. 191–204.
14. M. F. Cox, O. Cekic, B. Ahn and J. Zhu, Engineering Professionals' Expectations of Undergraduate Engineering Students, *Leadership and Management in Engineering*, **12**(2), 2012, pp. 60–70.
15. G. Dall'Alba, Learning professional Ways of Being: Ambiguities of Becoming, *Educational Philosophy and Theory*, **41**(1), 2009, pp. 34–45.
16. A. R. Bielefeldt, K. Paterson, C. Swan, O. Pierrakos, D. O. Kazmer and A. Soisson, Spectra of Learning Through Service programs, *Proceedings of the 2013 ASEE Conference*, Atlanta, GA, June 2013
17. A. R. Bielefeldt, K. Paterson and C. Swan Measuring the value added from service learning in project-based engineering education, *International Journal of Engineering Education*, **26**(3), 2010, pp. 535–546.
18. H. M. Matusovich, W. Oakes and C. B. Zoltowski, Why women choose service-learning: Seeking and finding engineering-related experiences, *International Journal of Engineering Education*, **29**(2), 2013, pp. 388–402.
19. A. W. Astin and L. J. Sax, How undergraduates are affected by service participation, *Journal of College Student Development*, **39**(3), 1998, pp. 251–263.
20. A. W. Astin, L. J. Sax and J. Avalos, J. Long-term effects of volunteerism during the undergraduate years, *Review of Higher Education*, **22**(2), 1999, pp. 187–202.
21. D. E. Giles and J. Eyler, The impact of a college community service laboratory on students' personal, social, and cognitive outcomes, *Journal of Adolescence*, **17**, 1994, pp. 327–339.
22. W. C. Oakes, C. B. Zoltowski, K. Schmotzer and A. P. Valenca, Integration of Curricular and Extra-Curricular Learning Through Service, *Proceedings of the 2015 ASEE Annual Conference*, Seattle, WA, June 2015
23. C. B. Zoltowski and W. C. Oakes, Learning by Doing: Reflections of the EPICS Program, *Special Issue: University Engineering Programs That Impact Communities: Critical Analyses and Reflection, International Journal for Service-Learning in Engineering*, 2014, pp. 1–32.
24. E. J. Coyle, L. H. Jamieson and W. C. Oakes, EPICS: Engineering Projects in Community Service, *International Journal of Engineering Education*, **21**(1), 2005, pp. 139–150.
25. W. C. Oakes, M. C. Hsu and C. B. Zoltowski, Insights From A First-Year Learning Community To Achieve Gender Balance, *Proceedings of the 2015 Frontiers in Education Conference*, El Paso, Texas, October 2015.
26. G. R. Pike, R G. Bringle and J. A. Hatcher, Assessing Civic Engagement at Indiana University—Purdue University Indianapolis. *New Directions for Institutional Research*, 2014, pp. 87–97.
27. I. M. Yob, Keeping students in by sending them out: Retention and service-learning, *Higher Learning Research Communications*, **4**(2), 2014, 35–57.
28. R. G. Bringle, J. A. Hatcher and R. N. Muthiah, The role of

service-learning in the retention of first-year students to second year, *Michigan Journal of Community Service Learning*, **16**(2), 2010, pp. 38–49.
29. C. M. Cress, C. Burack, D. E. Giles, J. Elkins and M. C. Stevens, *A Promising Connection: Increasing College Access And Success Through Civic Engagement.* Boston, MA: Campus Compact, 2010.
30. S. Gallini and B. Moely, Service-learning and engagement, academic challenge, and retention, *Michigan Journal of Community Service Learning*, **10**(1), 2003, pp. 5–14.
31. J. R. Keup, The impact of Curricular Interventions on Intended Second-Year Enrollment, *Journal of College Student Retention*, **7**(1–2), 2005, pp. 61–89.
32. K. S. Lockeman and L. E. Pelco, The relationship between service-learning and degree completion, *Michigan Journal of Community Service Learning*, **20**(1), 2013, pp. 18–30.
33. M. H. Mungo, *Closing the gap: Greater retention and achievement through service-learning at Wayne State University*. (Doctoral Dissertation), 2015.
34. S. C. Reed, H. Rosenberg, A. Statham and H. Rosing, The effect of community service learning on undergraduate persistence in three institutional contexts, *Michigan Journal of Community Service Learning*, **21**(2), 2015, pp. 22–36.
35. T. T. York, *Exploring service-learning outcomes and experiences for low-income, first-generation college students: A mixed methods approach*, (Doctoral Dissertation). 2013. Retrieved from ProQuest.
36. E. Tsang, E. (Ed.). *Projects That Matter: Concepts and Models for Service-Learning in Engineering.* Washington DC: AAHE, 2000.
37. L. Piket-May and J. Avery, Service-learning First Year Design Retention Results, *ASEE/IEEE Frontiers in Education Conference*. October 10–13, 2001, Reno, NV.
38. J. L. Huff, C. B. Zoltowski and W. C. Oakes, Preparing Engineers for the Workplace through Service Learning: Perceptions of EPICS Alumni, *Journal of Engineering Education*, **105**(1) 2015, pp. 43–69
39. J. L. Huff, C. B. Zoltowski, W. C. Oakes and R. Adams, Making Sense of Design: A Thematic Analysis of Alumni Perspectives, *Proceedings of the 2013 ASEE Annual Conference*, Atlanta, GA, June 2013.
40. A. Cummings, J. Huff, W. C. Oakes and C. B. Zoltowski, An Assessment Approach to Project-Based Service Learning, *Proceedings of the 2013 ASEE Annual Conference*, Atlanta, GA, June 2013.
41. J. Cohen, P. Cohen, S. G. West and L. S. Aiken, *Applied multiple regression/correlation analysis for the behavioral sciences* (third edition). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc., 2003.

William (Bill) Oakes is the Director of the EPICS Program and a Professor and a founding faculty member of the School of Engineering Education at Purdue University. He is a registered professional engineer. He has been active in dissemination of service-learning and community engagement for university and K12 engineering programs. He has received numerous awards for his efforts at Purdue including elected as a fellow of the Teaching Academy and listed in the Book of Great Teachers. He was the first engineer to receive the US Campus Compact Thomas Ehrlich Faculty Award for Service-Learning. He was a co-recipient of the US National Academy of Engineering's Bernard Gordon Prize for Innovation in Engineering and Technology Education, recipient of the US National Society of Professional Engineers' (NSPE) Educational Excellence Award and the American Society for Engineering Education's (ASEE) Chester Carlson Award for Innovation in Engineering Education. He is a fellow of the ASEE and the NSPE.

James Huff is an assistant professor of engineering at Harding University, where he primarily teaches multidisciplinary engineering design. He directs multiple student projects that use human-centered design in the context of community engagement. Additionally, Dr. Huff's research is aligned with unpacking psychological experiences of identity in professional domains. James received his PhD in engineering education and his MS in electrical and computer engineering, both from Purdue University. He received his bachelor's in computer engineering at Harding University.

Carla B. Zoltowski is an assistant professor of engineering practice in the Schools of Electrical and Computer Engineering and (by courtesy) Engineering Education at Purdue University. She holds a BSEE, MSEE, and PhD in Engineering Education, all from Purdue. Prior to this she was Co-Director of the EPICS Program at Purdue where she was responsible for developing curriculum and assessment tools and overseeing the research efforts within EPICS. Her academic and research interests include the professional formation of engineers, diversity and inclusion in engineering, human-centered design, engineering ethics, leadership, service-learning, and accessibility and assistive-technology.

Devendra Canchi has a PhD in Applied Economics from Purdue University (West Lafayette). He is currently working with Monitoring Analytics, the independent market monitor for PJM Interconnection, the largest wholesale electric power market in the United States. Mr. Canchi's work is primarily focused on developing metrics to assess the efficiency and competitiveness of constantly evolving electric power markets. Mr. Canchi's previous work involved developing arbitrage pricing models for financial contracts traded in electricity markets and examining the conduct of auctions in the electricity markets.