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Why Women Choose Service-Learning: Seeking and Finding Engineering-Related Experiences*

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As a field, engineering remains challenged with regard to gender parity and ethnic diversity despite efforts over the last 20 years aimed at closing such gaps. Although research and curricular reform efforts have advanced our understanding of what works to attract women to engineering, we still know little from the student perspective as to why some practices are successful in attracting and retaining women. It is not enough to know what works, but we must also know why some practices work in order to create lasting change and reach diversity goals. Our study begins addressing this why question by qualitatively examining eight women participants' choices to enroll in a service-learning course (Engineering Projects in Community Service (EPICS)) that has been successful in attracting women over 16 years. Our results show that our participants choose EPICS as a way to gain experience doing engineering; that EPICS provides the benefit of contextualized learning with resulting impacts within EPICS and in other classes, and that EPICS positively impacts commitment to engineering. Interpreting our results, we argue that women are seeking ways to gain engineering experience in a setting that is comfortable to them, such as EPICS. The context of the experience and ability to help others is important, but secondary to gaining engineering experience.

Keywords: service-learning; self-efficacy; gender

1. Introduction and problem statement

Despite calls for an increase in the number and diversity of engineering graduates [1–4], a gender disparity still exists in graduates from engineering and related fields [5–9]. Lack of gender parity in engineering has perhaps been a problem since the very start of engineering education as Hacker [10] describes the masculine culture of engineering as stemming from the military origins of the field. However, the conversation about the lack of women in engineering has grown in momentum over the last 30 years, suggesting that approaches to promoting diversity have not been effective. The problem then is not only that gender disparity exists, but the problem is also an inability to make significant progress in closing the gap over time. This lack of change suggests that a new approach to understanding the complex problem of underrepresentation of women is needed.

Historically, research has often focused on what could work (e.g., developing and testing outreach programs [11]) and factors that cause and contribute to the sustained gender disparity (e.g., person–thing orientations [12]). More recently researchers have begun to examine what does work and why. For example, Brawner *et al.* [13] demonstrated through a large, multi-institutional database that industrial engineering (IE) is successful at attracting and retaining women across all four years. Looking at reasons why, their study challenges popular perceived beliefs about why women pursue industrial engineering, namely that it is an easier major, finding instead that women more often talk about pursuing IE because of perceived characteristics of the field such as warmth, flexibility of future career options, the nature of the work in the field itself and the perceived sociability of the field.

We adopted an approach that is consistent with this current research and investigated a pedagogy that is already working to attract women, and then we looked at the student perspective to understand why the approach is working. Specifically, we studied a service-learning program, Engineering Projects in Community Service (EPICS), which successfully attracts women. Moreover we used qualitative interviews with eight women to highlight the student perspective as to why women are drawn to EPICS at higher rates than their representation rate in their respective majors. Our research shows that EPICS attracts women who seek experiences doing engineering, that EPICS provides the benefit of contextualized learning that increases learning within EPICS and in other classes, and EPICS

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positively impacts commitment to engineering. Moreover, our findings support self-efficacy theory as promising to understand the gender gap in engineering. By providing the student perspective on *why* EPICS is attractive to women, this research makes the important contribution of helping us understand why a pedagogical practice that is effective in increasing diversity actually works.

2. Context of EPICS

EPICS is an academic program that supports a series of design courses that engage students from many majors and academic years in the development of designs for local and global communities. EPICS situates the design experience within a service-learning context [14]. Design teams, comprised of students from a variety of engineering and non-engineering majors, partner with community organizations, agencies or schools that have needs that can be addressed through technology. The goal is a mutually beneficial experience where a functional product satisfies the needs of the community partner while providing a hands-on, "real-life" design learning environment for the students. The projects are scoped to meet the needs of the community partner, not the length of the semester, with projects often spanning multiple semesters or even years. EPICS was started in 1995 and has grown to engage over 400 students per semester working on more than 80 projects for more than 30 community partners. EPICS has been recognized with national awards within engineering education and service-learning including the Bernard M. Gordon Prize for Innovation in Engineering and Technology Education by the National Academy of Engineering (NAE) [14].

The EPICS design teams are multi-disciplinary with over 70 majors (engineering and non-engineering) represented throughout the program [15]. The teams are also multi-level by incorporating first-year through fourth- or fifth-year senior students. Within the teams, students self-select or elect roles such as team leader, project leaders, community liaison, financial officer, etc. The students meet as teams regularly to work, and also meet with faculty or industry advisors and teaching assistants (TAs) for guidance. Additionally, students attend regular lectures on topics of general interest to all project teams.

Students can choose to enroll in EPICS in every semester of their undergraduate years and can start as early as their first-year in the first-year engineering program at Purdue. They may choose to take the course for one or two credits per semester with the workload being proportional to credit hours. EPICS is a voluntary course and may be counted towards graduation as a technical or lab elective in most engineering departments and as a senior capstone design experience in a few [15]. Outside of engineering, EPICS can be used as elective credits within majors, as a substitute for core requirements, such as the Liberal Arts ethics and social responsibility core, or as a course option for the university's entrepreneurship certificate. EPICS has become a national model for integrating service-learning into the engineering curriculum.

The benefits of service-learning have included increases in students' professional skills such as teamwork, communication and life-long learning [14, 16]. There has been a great deal of research around the positive impact on students' perceptions of themselves and their communities as a result of their service-learning as well as their involvement in and views of civic engagement [17, 18]. Reflection, the metacognitive process that is such a critical component to service-learning, has been shown to enhance learning of subject matter and critical thinking [19, 20]. Astin *et al.* [21] examined the impact of service-learning across a sample of more than 22,000 undergraduates within the United States, controlling for the impact of volunteering outside of class, to assess the impact of curricular service-learning. The result was an increase in academic outcomes from participation in a course-based service experience [21]. In addition to learning gains, service-learning has been linked specifically to increases in student retention in science, technology and engineering [22–24].

3. Quantitative data: Female participation rate in EPICS

Enrollment data for Electrical/Computer and Mechanical Engineering students indicate that EPICS is in fact attracting women participants at higher rates than their representation rate in their respective engineering majors. These majors have the largest enrollments in the College of Engineering and are the majors with the highest rates of participation in EPICS from both men and women. Enrollment data for twenty consecutive semesters were analyzed for the participation rates of women in EPICS from Electrical/Computer and Mechanical Engineering. In these twenty semesters, the participation rates were consistently higher than the percentages of women in their respective majors, with only two exceptions. In two semesters, the percent of women dipped slightly below the school average in Mechanical Engineering. Over the twenty semesters, the average participation rates of women in EPICS were more than 70% higher than in their respective majors, as seen in Fig. 1. Note that Electrical and Computer Engineering are combined as they are part of the same school.

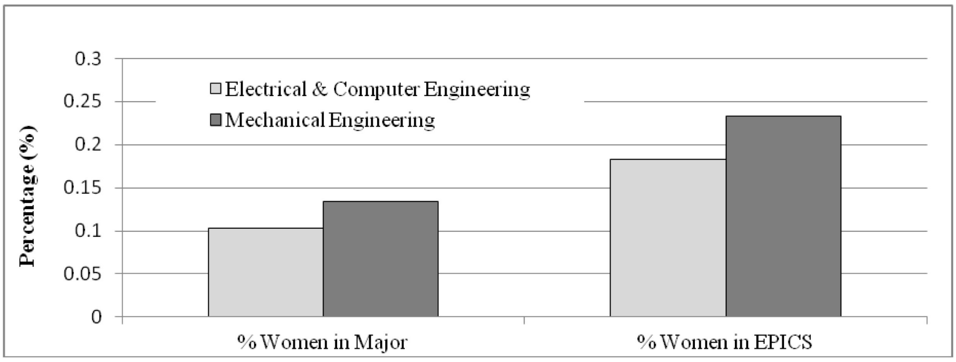

Fig. 1. Average enrollment of women from Electrical/Computer and Mechanical Engineering in EPICS at Purdue over twenty semesters.

Moreover, in addition to higher rates of participation, women have also taken on team leader roles at a relatively higher rate. For example, when women accounted for 20% of the students in EPICS, women represented 30% of the team leaders [15].

In considering this data, it is important to note that EPICS is an elective class that can be substituted for: 1) technical electives in Mechanical Engineering, and 2) technical, lab elective and an option for capstone design in Electrical and Computer Engineering. This means that women have to choose to enroll in the EPICS class because it is not required. Therefore, the higher rate of participation shows that they are drawn to the class. The next step is to understand *why*.

4. Methods

Given the continued gender disparity in engineering, the enrollment rates of women in EPICS are both encouraging and worthy of further investigation. The enrollment rates do not indicate why women choose EPICS though. Therefore we conducted a qualitative exploratory investigation to further examine women's enrollment in EPICS with the hopes of capturing findings that can be leveraged further within EPICS, service-learning and across engineering programs at Purdue and other universities. We addressed the following questions:

- Why do women engineering and computer science students enroll in EPICS at Purdue?
- What benefits do women describe as coming from participation in EPICS at Purdue?

This type of exploratory study, from the student perspective has not been conducted for an elective service-learning class like EPICS. Understanding why the EPICS program is attractive to female engineering students, from their perspective, could help further development of recruitment and retention strategies for EPICS and the broader STEM community.

To answer our research questions, we used case study methods [25]. In case study research, defining the bounds of the study is of primary importance [25, 26] because case studies are not intended to cover all possibilities. Case studies use multiple data sources to develop a deep and rich understanding of a particular context [27] rather than the broad generalizations that often come from survey work. It is suggested to start with 5–15 cases so that there is diversity, yet enough similarity to extract meaningful themes and patterns from the data [25]. Because the sample is small we seek transferability to other settings rather than generalizability. Therefore, understanding what cases are included and excluded helps establish the possible transferability of the research. For this study, our bounds are eight cases, all women, all enrolled in EPICS during the same year (Spring or Fall semesters of 2006). As part of defining the bounds, participants in this study are intentionally all women. The purpose of this study is to understand the perspective of a group of women students enrolled in EPICS and not to draw comparisons with male students. Instead the intention is to explore themes consistent with the literature regarding effective recruitment and retention strategies for women as well as identify new themes. Expanding the bounds to include additional participants, including men as well as women who choose not to enroll in EPICS, is described as part of the future work. This approach of starting with a smaller sample and expanding to a more inclusive sample in future work is consistent with case study research practice [25].

4.1 Participants

After receiving approval to conduct human subjects' research from the appropriate institutional review board, participants were recruited during the Spring and Fall semesters of 2006. During the Spring semester of 2006, 46 female engineering students enrolled in the EPICS program were asked via e-mail to participate in semi-structured interviews. Six students volunteered to participate; all were interviewed. Five of the six participants were currently enrolled in their first semester of EPICS. After preliminary analysis of the interviews, it was determined that the data was not saturated with regard to the perspective of students who had participated for multiple semesters. A second e-mail, targeting seven female students who had been enrolled in EPICS for multiple semesters, was used to recruit additional study participants. Two students volunteered for participation and were interviewed. This study incorporates a combined total of eight participants.

Participants include second, third, fourth, eighth and ninth semester students in a variety of engineering majors including Mechanical Engineering (ME), Electrical Engineering (EE), Electrical and Computer Engineering (ECE), Industrial Engineering (IE), and Multi-disciplinary Engineering (MDE). Estimated GPAs ranged from 2.5 to 3.7, as self-reported by the participants. Table 1 includes the pseudonym and descriptive information for each participant. Specific majors are not included to prevent possible identification of the participants. During the course of the interview, one student identified herself as an international student. Ethnicity or country of origin information was not collected on the balance of the students.

Stake [25] suggests that multicase studies should incorporate sufficient data to explore the phenomenon without being overwhelming with case diversity. To accomplish this, between five and fifteen cases are suggested. As described in the preceding paragraph, the eight participants represent diversity in major and number of semesters in EPICS. While not every possible case is represented, it is believed that this case variation covers a sufficiently broad space for an initial exploration into the phenomenon of why women choose to enroll in EPICS without adding excessive diversity.

4.2 Data collection and analysis

A single interviewer (first author) conducted one-on-one interviews, approximately one-hour in length, with all participants. The interviewer was not associated with the EPICS program and was a graduate student at that time. Six interviews were conducted within a four week period during the spring 2006 semester and the remaining two interviews were within a one week period at the end of the fall 2006 semester. Semi-structured interviews with open-ended questions provided the students an opportunity to talk about and actively reflect on their experiences in the EPICS program, engineering in general, and their major. The interview protocol is included as Appendix A.

The interviews were audio-recorded and transcribed. Each interview was read repeatedly to allow patterns and themes to emerge inductively from the data. Open-coding strategies were used with Atlas Ti software. Cross-case analysis, as described by Miles and Huberman [28], was the guiding approach such that patterns and themes were inductively developed on an individual case basis then compared across cases. With each successive pass through all of the interviews, the codebook was revised such that codes with sufficient overlap were combined and remaining codes were uniquely identified and had clear, distinct rules for use. A sample of the codebook is shown in Table 2. Consistent with a variable-centered approach (i.e. one where the variables take precedence over the individual cases [28]), the results are presented in terms of the themes identified across cases rather than the characteristics of individual cases.

Through the analysis of the first six cases it was determined that the data were not saturated particularly with regard to students enrolled for multiple semesters. Only one of the initial participants had been enrolled in EPICS for multiple semesters. As previously described, additional participants with multiple semesters of experience in EPICS were recruited and two were interviewed. The standardized list of codes (Table 2) were applied to these two interviews. Although the coder was open to additional codes, none were found.

4.3 Research quality

The quality of research is measured through the validity and reliability of the study [29]. Although qualitative researchers often use credibility and/or

Table 1. Study participants

Name	Level (Year)	No. semesters in EPICS	Self-reported GPA
Carol	Second	1	2.6
Jean	Second	1	3.7
Hanna	Fourth	1	2.9
Elaine	First	1	3.4
Corina	First	1	2.5
Maggie	Fourth	7	2.6
June	Fifth	2	3.7
Molly	Second	2	2.5

Table 2. Sample codes and rules of use

Code	Rules of use
EPICS as proving engineering skills	1. Specifically mention résumé. 2. Talk about things of interest to employers (or inferred employers).
Team Experience	1. Talk about working with students of different "grade levels". 2. Talking about team environment. 3. Talking about working with students in different majors.
Getting engineering experience	1. Mentioned hands-on. 2. Described getting experience actually building or designing. 3. Mention learning about or wanting to learn about design process. 4. Mention using design process or doing design work or wanting to. 5. Mention "real-world" experience.
Commitment to engineering	1. Talk about future career plans. 2. Talk about commitment to being an engineer.

transferability [30] as measures of quality, Yin [27] uses validity and reliability for case study research. Several features were incorporated into the design of this study to address research quality. We used researcher triangulation [26, 27, 31] and established a chain of evidence [27] to demonstrate construct validity. We demonstrate external validity through replication/triangulation of findings across cases [25, 27, 32]). Internal validity is typically not an appropriate measure for exploratory studies such as this one [27]. Finally, establishing a chain of evidence also enhances reliability.

Researcher triangulation includes data analysis procedures where more than one researcher examines the data. In this study, we used peer debriefing [29]. After coding of the interviews by the primary author, sections of text from six of the eight interviews were shared with a group of four peer researchers who were not otherwise involved in this project. The researchers independently reviewed the sections of text then met together and discussed the codes, and subsequently emerging patterns and themes. Disagreements over codes were very few and were quickly resolved through discussion. The discussion on themes and patterns was more impactful on this analysis. As a group we tested an assertion that the service aspect was an important factor in attracting women to EPICS and found that it did not hold. Through a discussion of how the participants talked about community the group recognized that although participants mentioned community, they were not very articulate about who the community was, what community meant to them, or even what it was like to work with the community partner. As a group we reached consensus that we could not clearly describe the meaning of the service aspect to the participants and that it was not represented in the interviews as a primary attraction for most interview participants. This was an important check on the trustworthiness of the data because our findings go against a popular belief that women prefer activities associated with helping people. While our findings do not say that the community context was not important, it does show that this was not the primary attraction for participation.

Establishing a chain of evidence refers to presenting results in such a way that the reader can follow the development of and interrelationships between evidence and conclusions. The reader should be able to recreate the story in either direction, from the research questions to the conclusion or the reverse [27]. To establish a chain of evidence, this document includes detailed descriptions of: 1) the data sources and collection methods, and 2) analysis process including development and application of the codes. The appendices include the interview protocol. As a further verification of construct validity, the interview protocol was pilot-tested with a student volunteer enrolled in the EPICS program prior to the first formal interview. The intent was to be sure the questions covered appropriate content related to the research questions and that they were asked in such a way as to make sense to the students. Feedback was solicited from the student volunteer. The recorded interview was reviewed by a second author to identify potential areas of interviewer bias and feedback was given to the interviewer.

Having external validity ensures a study's findings are generalizable to a specified domain [27]. Using multiple cases helps ensure external validity by allowing for replication of findings across cases [27] (also called triangulation across cases [25] and hypothesis testing across multiple cases [32]). In this study, case by case analysis preceded analysis across cases. Also, two additional cases were added after the initial analysis. These cases were intentionally added to represent the perspective of students enrolled in EPICS for multiple semesters. Findings from the first six cases were tested with these additional two cases.

5. Results

Results are organized in three sections. The first section establishes participants' reasons for choos-

Table 3. Reasons for choosing EPICS

Reason	Participants
Getting engineering experience	Elaine, Carol, Molly, Maggie, Jean
Community service/Helping people	June, Jean
Required Class	Carol
Easy "A"	Hanna

ing EPICS. The second section includes reported benefits of participation in EPICS. Finally, we present results related to commitment to engineering majors.

5.1 Reasons for choosing EPICS

Table 3 shows the participants and their reasons for choosing EPICS. The most often cited reason the participants reported for enrolling in EPICS was to "get engineering experience". Note that Jean cited both of the top two reasons, getting engineering experience and community service. For Carol, "being a required class" was the bottom-line reason but she also gave rich descriptions of her expectations of getting engineering experience. It is believed that even if it were not a required class, she would take EPICS for these reasons. Finally, Hanna enrolled in EPICS simply because she heard it was a way to "get an easy A".

5.1.1 Getting engineering experience

The predominant reason for most study participants choosing to enroll in EPICS was to obtain engineering experience. They described this as "hands-on", "real-world/life" or "design" experience. These women value this experience as a way of developing their own skill sets and/or to improve their résumés for prospective employers.

Five out of eight students mentioned this as a primary reason for choosing EPICS. For example, when asked why they enrolled in EPICS or about their expectations going into EPICS, Elaine and Carol talked about design experience:

> . . . the whole process of being able to have a customer and being able to meet the customer's needs and deadlines and stuff, so I guess there's a whole design process . . . plus being able to use mechanical engineering in real-life situations (Elaine)

> I think on the technical side I would like to learn the design process and creating a job . . . but that's something I really would like to say I've accomplished by the end of it. I'd like to be able to say "I've designed this, I built this, I've led this to where it was being implemented later", I would love to say that. (Carol)

Similarly, Molly's expectations for EPICS include an example of a practical engineering experience:

> . . . I went to the call-out, not really sure what to expect and I kind of got the idea that it was an open environment where you could kind of like just put your ideas out there and get immediate feedback and so that's kind of why EPICS appealed to me. (Molly)

In general the participants enrolled in EPICS not only to obtain the engineering experience but also as a means of proving that they have engineering skills:

> . . . of course, the résumé' thing, it looks good on a résumé because you're getting real-world experience and of course like being able to talk during interviews for internships and jobs that you can say "oh I was involved in EPICS and we did these" and it's more real-world experience and problem-solving and like instead of just saying you know "I got an A in physics or something" you could say "I actually did this stuff. . ." (Elaine)

> It looks good on your résumé (laugh), that's what most of the motivation is for most students. (Maggie)

While Elaine, a first semester participant in EPICS, is speaking for herself, Maggie has been in EPICS for seven semesters and is speaking on her perception of other students' reasons for joining EPICS.

Jean's description of her primary reason for enrolling in EPICS is particularly rich:

> What I wanted out of EPICS was to get some experience outside of my class work. I know everyone that is coming to Purdue looking for students needs something to show that they've been doing something besides coursework. And, I don't have any experience in engineering. I came in with no AP credit, no any experience from going to work with my dad, I mean that was basically it. And, I don't have anything that says I've been working with tools or anything like that. I know a lot of guys work on cars, I have nothing of that. So, I knew that EPICS was something that I could definitely get hands-on experience that shows that I'm doing something productive outside of class, so—to learn more about my major. (Jean)

Jean makes one of the few comparisons with male students found in the interviews. While students were not asked to make this type of comparison, Jean's perception of her male counterparts is important to her. As with Maggie and Elaine, Jean believes there is a need to demonstrate to others, such as potential employers and recruiters, that she can physically do engineering activities and not just complete coursework. She also viewed EPICS as a place where she could acquire that experience.

5.1.2 Community service/Helping people

Two participants expressed a strong interest in joining EPICS as a means for helping people. For June, this was the primary attraction to the program because it is in line with her desire to do not-for-profit work in the future:

> . . . I really would like to incorporate not-for-profit and so this work, and in my future that's what I'd love to do, use med—the medical information I have to do not-for-

> profit work eventually. And so then I thought, well EPICS is right here, it's doing the same thing as I want to do, it combines everything . . . (June).

June goes on to explain that gaining hospital experience through her design project is more important to her than maximizing the use of skills developed in her major.

June has chosen EPICS as the way to fulfill her senior design requirements because it is in line with her future career plans. For Jean, the desire to help people was secondary to obtaining (and proving she has) engineering experience but still important to her. When asked about her expectations from the EPICS program:

> I hope to get out of it some sort of feeling that I made a difference in—in the community and by putting my time in EPICS that there would be some benefit to other people in the community and it doesn't necessarily have to be a number difference, like I saved this much money because she was in EPICS, but um to make a difference maybe by just talking to them and telling them something that could be useful for them in their house. (Jean)

Jean is very driven by the idea of helping the community and self-reported that she earned the role of "community outreach person" through her efforts to continually bring her team's focus back to the community.

Although it was not the primary incentive reported for participation, the community context and the ability to help were notable characteristics of the program for the other women participants. Other participants typically mentioned community in response to questions related to describing EPICS to someone unfamiliar with the program. For example, when asked how she would describe the EPICS program to another student that is not familiar with it, Hanna responded:

> EPICS is applying your knowledge and skills in helping the community. You're actually presenting yourself and helping the community [partner]. I'm an engineer and I can help you—I think that's what this is. (Hanna)

The community context is a recognized feature of the program, but in this case it is seen more as a benefit. The participants view work as generally helping, and benefitting the community. However, for most, like Hanna, the community was not the primary motivation for their participation.

5.2 Benefits from participating in EPICS

Participants cite two primary benefits associated with participating in EPICS. These include contextual learning/learning in context and team environment. As shown in Table 4, half or more than half of the participants selected each of these categories.

5.2.1 Contextual learning and putting learning in context

Consistent with citing a desire to obtain engineering experience as the primary reason for enrolling in EPICS, the primary benefits from EPICS relate to context and learning. This includes EPICS as contextual learning, by which we mean applying science and engineering concepts, principals, equations, etc. in the context of a real problem. This also includes taking the learning from EPICS and using it to provide context for learning in other classes or "putting learning in context". By this we mean that when faced with text-book problems in other courses, students can make more meaning from those problems by imagining how such problems might relate to a real problem such as those they experience in EPICS. In describing EPICS as having context, participants identified that EPICS problems are real problems and solutions must actually work:

> So in EPICS you actually see what the problem is, you actually physically see that their bills are $1000 per—per month to heat their house, um, so that's the problem. But, in [engineering class] you see the problem is "well what's the final velocity in", and so it's—I think EPICS makes it easier to learn because you know what you're learning. (Jean)

> So in [engineering class] one of the problems we had to solve was more of like an industrial engineering question or problem where you had to be able to ah put different machines in a plant and be able to like minimize the distance a product has to travel before it is complete between each of the machines. And, I—like looking back because of my EPICS experience—I can look back at our solution to that problem and say like a lot of different things that wouldn't work. . .So, with EPICS like you have to—you truly do have to look at all angles of a prob—problem and ah make sure that it will work in real life instead of just one aspect—having to solve that one aspect. (Elaine)

> . . . it does give me a place to kind of act as a sounding board for ideas that I have. It gives me the resources I need, and tools that I need, the people I need to, um, help serve my project partner, and actually do something. (Molly)

> Like building a project from scratch pretty much—like having to actually go out and purchase parts and then going to the lab and build it all. (Maggie)

Unlike paper and pencil problems experienced in many classes, in EPICS students must directly

Table 4. Benefits from participating in EPICS

Reason	Participants
Contextual learning/Learning in context	Jean, Elaine, Molly, Maggie, June, Hanna, Corinna
Team environment	Hanna, Corinna, Carol, Elaine

consider their client, safety, purchasing supplies and other factors. They must construct a finished product that works for their community partner. In addition to recognizing that solutions must work, participants see that there are multiple possible solutions in EPICS projects:

> So far I've gotten out of it that there are some problems that are just abstract and there's not necessarily going to be a conclusion or a way to fix it . . . I think that kind of opened my eyes to the reality that it's –there's more than just one answer and there's more than one way to do things and—and there's different ways of going about doing it. (Jean)

Not only are the EPICS problems themselves contextual, but EPICS can create context for other classes. Participants indicated that EPICS is also a place where they can apply what they have learned in other classes:

> . . . you apply what you have learned in your other classes, so it puts it all together . . .

> . . . I feel like I appreciate the education and the tools that I have now more than I did when they were laying useless or just going for a grade. I feel like I appreciate the abilities and skills that Purdue has helped develop and use, 'cuz I've seen them in action. (June)

> . . . I take a physics class and I think "I'm never going to use this," and I'm actually seeing that I'm actually using it and so the connection to like the hard science classes and engineering is kind of coming together. (Molly)

> So, it was a lot different than the theory, you know, like school stuff. It was actually applying it, so it was a lot different. (Hanna)

> And, um, I don't know I think [EPICS has] just been like a really positive experience because, I don't know, freshman year kind of sucks because you get no application of what you're learning. Like, it's just you know chemistry, physics, computer programming, mat, like—and that's pretty much what you learn. And, there's not really anything that shows you what you're doing is like you're actually gonna use it. (Corina)

Participants also indicate that they learn things in EPICS that will be helpful in other classes.

> One thing is applying my knowledge. I think word problems are a lot easier now just because I can more visualize what kind of a—what kind of a problem they're having especially in thermo—just 'cuz I—heat efficiency and thermodynamics go a lot together. But, applying my knowledge and using it in other areas is a big thing that I've learned through EPICS (Jean)

> [EPICS] puts relevancy into your actual other classes. (Elaine)

> . . . I learned how to find like the torque and stuff on an engine and the power it can provide before I learned that in physics, so that made that easy (laugh). (Corina)

Students enrolled in EPICS mainly to get engineering experience. They find that this experience is helpful in perhaps more ways than they originally anticipated because it gives context to their other classes.

5.2.2 Team environment

Although not cited as a reason for choosing EPICS, the study participants are generally positive in commenting about the team experience and how it enhanced their learning. This is particularly noted with regard to being multi-level and/or multi-disciplinary. As an example, Hanna talks about the value that different majors can contribute to the team as a whole:

> I learned a lot about, what—how civil engineers and how mechanical engineers could—could put there, like how much they knew and what areas they were good in and it was really good to have people from different majors. (Hanna)

Corina mentioned working with upperclassmen and how it has helped her learn about circuits:

> I like that I don't know what everybody's talking about because um like a lot of people on my team are EE's and they're like juniors and seniors so like I've learned a lot about like—well like circuits and stuff just from listening to them. (Corina)

> After talking about some of the frustrations that can arise when "marketing" and "technical" people try to communicate, Carol says that diversity of majors is a positive attribute of EPICS, ". . . I think it's a good thing. I think that to make your best product you need a well-rounded group of individuals." (Carol)

Overall, the students recognize and value that they are learning through their peers who are in different majors and their peers who are at more advanced grade levels. In addition to enhanced learning, the diversity of the teams and project needs makes the environment feel more inclusive for Elaine:

> I was like well, I don't know engineering, I don't know you know how—I don't know anything about motors, I don't know anything about you know harder classes that I'll be taking later 'cuz I just haven't been exposed to that, and so I was ex—I was an expectation or something if you want to call it that, but I was worried that I wouldn't be able to contribute—I wouldn't be a—a key role or anything like that. But um, but that's not the case at all, like you—there's definitely so many different roles that you can take on. (Elaine)

This student found that there were enough different activities and roles within the team that she could contribute using her knowledge and experience base.

The students also associate "project management" type skills with the team structure of EPICS. They learn how to communicate and work with people from different backgrounds both within the team and with the community partner. They learn time management skills and learn about leadership.

5.3 Increased commitment to engineering

For all but one student, EPICS increased or reinforced their commitment to engineering. Molly was the one student who did not report EPICS as increasing or reinforcing her commitment to engineering. However, she did still report insights into engineering as a career as a result of participating in EPICS.

As an example of impacting commitment, Elaine was very committed to engineering before EPICS but EPICS helped make her undergraduate classes more tolerable:

> I don't think changed [EPICS], more enforced it. Like it helps thinking "okay, I can get through my classes and then I'll be able to do something more actually pertaining to life" (laugh), instead of just studying all the time. (Elaine)

Similarly, Corina talked about EPICS helping her stay in engineering by adding relevance to her early classes:

> . . . your freshman year you're kind of just taking like basic classes like math, chemistry, physics and I really wanted to get an idea of what engineering, like what you could do with that information instead of just like, "okay now I know how to find a chemical equation or something, now", like I just wanted to get some like experience in it so that, I don't know, I guess that it kind of makes me want to stay in engineering and like know that this is what I want to do. (Corina)

When asked how her learning has changed over the seven semesters she has participated in EPICS, Maggie responded that it helped her stay in engineering "ultimately". When asked why she responded,

> . . . seeing how it's applied rather than just like [in] class learning materials and taking tests like, you can see how like working in interdisciplinary teams works. Like, I didn't understand the meaning of that when I first like joined EPICS 'cuz like they emphasize that a lot. And I didn't understand it until I actually got in it and used—you actually have to work with other people 'cuz just your field of expertise won't be enough for some of the projects. (Maggie)

EPICS helped Maggie see how engineering is applied and what it really means to work in an interdisciplinary team and this contributed to Maggie staying in engineering. Jean was committed to engineering from the start and EPICS reinforced her choice. When asked if EPICS impacted her desire to pursue her specific field of engineering she answered:

> . . . because working with the community or working with someone else and trying to help them with a problem that can use technical information is very interesting to me and by . . . being able to apply things from—even just what I've learned from my classes as working with other people, into the project, it—it is something that I know that I want to do for the rest of my life. (Jean)

EPICS reinforced Hanna's decision to be an engineer. Hanna is an international student and described choosing engineering from a limited number of choices then learning how she could apply her knowledge and help people:

> Okay, well, because we're international students and you're paying a lot because you really want to get like a good job. And the second thing is that I had no interest in medicine or bio—or anything to do with that, or psychology which you had to learn a lot of stuff. I was in mathematics in high school so—I think engineering was the only thing I saw from there. (Hanna)

> Seeing how much you could apply what you've learned and for the other—in other areas for example, I never knew I'd be helping a school—a high school with my [major] knowledge I just thought maybe explaining them or using them project but I never knew it would actually apply to a simple [learning device]. So, I learned a lot in that way that the little things are things you could teach children a lot make things simpler. A lot more like how much you could use this thing and little things that you've never thought about. (Hanna)

Already committed to engineering through EPICS, June gained confidence in her career–related abilities reinforcing her ability to be an engineer. She describes how EPICS changed her view of her major:

> Sometimes I think of it as a company needs an electrical engineer, but on—on my own I didn't feel like I was as capable of creating something, and so realizing that until you've created something and so that was—so that's why that was an empowering experience. Um, but electrical engineering isn't just part of a worker bee within a larger project but they can be independent if needed. (June)

June is pursuing a career in the biomedical industry and believes that EPICS has helped her to understand how her major and her career interests can fit together.

Although, EPICS did not impact Molly's commitment to engineering it did help her understand engineering as a career better:

> So, engineering as a career, it's definitely taught me that it's not—you're probably not going to do—be doing one specific thing, where if you're a mechanical engineer you'll only do mechanics, if you're an electrical engineer, you will only do circuits, especially because a lot of the pieces that you're designing are component pieces and so you have to have an overall understanding of the project you're working on 'cuz most of the time it's going to combine mechanical–electrical, uh and chemical stuff, so you can't just—if you just focus on your part then it's not going to be a fit with the overall design. So, that's definitely what it's taught me about engineering in general. (Molly)

Molly has learned that engineers will need to work more broadly and their project-work will take them outside their specific discipline. She has also learned about different ways she could use her major:

> . . . within my major, different areas that I can go into besides just, um, entertainment media or um, audio, such as vibration control, noise control, things of that nature. (Molly)

Several other participants echoed Molly's beliefs that they learned about different applications of their major through EPICS.

6. Discussion

The purpose of this research was to provide evidence for and understand the higher enrollment rates of women in the EPICS program from the perspective of female students enrolled in the program. Research questions focus on why women engineering and computer science students enroll in EPICS and what benefits they derive from participation in EPICS. We will discuss the results in the context of current literature from three perspectives: women's self-efficacy, women in STEM, and service-learning.

6.1 Consistency with literature on women's self-efficacy

Our study found that women engineering students chose to participate in EPICS to get engineering experience. Women feeling less confident in engineering skills is in alignment with current research on women's self-efficacy and more broadly their competence beliefs. For example, among college students, Hutchison-Green *et al.* [33] found that while men believed they could out-perform their peers in a first-year engineering course, women had less confidence in their abilities, believing that their peers could out-perform them. Also, in a longitudinal study that spanned four undergraduate years, Matusovich *et al.* [34] found that women tend to redefine what it means to be an engineer so that it is consistent with the skills that they believe they have.

There is also evidence that women have lower self-efficacy and competence beliefs with regard to the types of hands-on activities prevalent in EPICS. For example, it has been suggested that in the United States entering college women tend to have less hands-on experience than men and may have anxiety or feel less prepared than their male counterparts particularly in computer science classes [35]. Investigating such anxiety, Shull and Weiner [36] found that it can be reduced through a hands-on course related to computer diagnostics and repair. In another example, examining gender differences in experiences and performance in a fluid mechanics course laboratory, Micari *et al.* [37] found that women were less confident than men in their ability to avoid mistakes in the lab, and perceived themselves as having less engineering ability than classmates and less skill in certain lab task but there were no gender differences in course engagement or performance. There are similar findings in research related to women's persistence in computer-related majors [38]. It should be noted that women facing a gap in engineering experience during their undergraduate years is not a new problem; published in 1992, *Women in Engineering: Gender, Power, and Workplace Culture* [39] highlighted insecurities felt by some women with regard to hands-on engineering activities. They noted that women were at a distinct disadvantage in many undergraduate engineering programs as a result of the prevalent cultural gender socialization that often pulls girls and young women away from tinkering, building, and engineering-type activities

It is not all bad news with regard to self-efficacy and competence beliefs. Research shows that while women often have lower belief abilities related to STEM fields, such beliefs do not predict poor performance in these fields [9, 34, 40–42]. Also, unlike in the US, women in India have a strong background in mathematics which contributes to confidence in their computing abilities and an overall rising rate of the number of women pursuing computing fields [43]. Perhaps most importantly, research has shown confidence-beliefs to be factors that educators can influence. For example, Khan [44] found that teaching strategies that include confidence-building are among the factors contributing to retention of women in the physical sciences.

The desire to reduce anxiety related to women's feelings of having less engineering-related experience than men and an increase in confidence-building activities could contribute to women seeking out engineering experiences like EPICS. Unfortunately, within engineering education the types of experiences that students perceive as building their engineering skills often come in the senior year. For example, Ortiz-Marco *et al.* [45] describe an individual, Final Year Project (FYP) where students, under the guidance of tutors or mentors, complete a project that meets a real need. Using a survey they demonstrated that students perceive the experience as contributing to their developing the engineering competencies outlined by ABET. However, this is where longitudinal programs such as EPICS can fill a gap by allowing women to get engineering experiences earlier. According to self-efficacy theory [46], mastery experiences contribute significantly to increasing beliefs about ability to succeed in certain tasks. Mastery experiences are those in which one masters a task of perceived difficulty. In our study, women perceive EPICS to represent engineering and then join EPICS seeking mastery experiences in engineering.

6.2 Consistency with literature of women in STEM fields

A number of characteristics have been cited as positive for attracting and retaining women in STEM programs: 1) opportunities for interactions with faculty members; 2) opportunities for peer mentoring; 3) an altruistic aspect, and 4) a team structure or small class environment. The EPICS program aligns well with each of these characteristics.

6.2.1 Interaction with faculty

According to Seymour and Hewitt [9], the strongest single need for female students in Science Engineering and Math (SME) fields is seeking connective relationships with faculty. Without connective relationships to faculty, female students can feel lost and unsupported [35]. Positive associations with professors have been shown to increase the self-confidence of women engineering students while also having a positive impact on persistence [47]. Each EPICS team has a faculty or industry advisor and teaching assistants who meet with the students on a regular basis to help guide the project. Although the teams vary in size, the overall team structure provides opportunities for meaningful interactions with both the faculty and teaching assistants.

6.2.2 Mentoring

The literature suggests that mentors in general, and specifically female faculty and student mentors, may contribute to the attraction and retention of female students [9, 41, 48–50]. Specific examples include: 1) undergraduate engineering women participating in a women's mentoring program were more likely to be retained in engineering than mentoring program non-participants [51] and 2) mentornet, an e-mentoring program increased undergraduate and graduate women's intentions to pursue careers in their chosen science or engineering fields [52]. The EPICS teams at Purdue are composed of students from all undergraduate grade levels and with differing levels of experience (number of semesters) in EPICS. The students work closely together managing all aspects of their projects including communication with the community partner, design progress, project documentation, etc. creating an environment ripe with opportunities to be mentored by more advanced students and to mentor less advanced students.

6.2.3 Altruistic career intentions

Research suggests that women prefer careers where they will work with people and/or serve society [53] or help people [54]. Seymour and Hewitt [9] found that within SME fields, women were more likely to choose SME fields for altruistic reasons while a failure to meet this need was a reason people leave SME fields. A meta-analysis of published and unpublished research conducted from 1970–1999 related to gender differences in occupational attribute preferences showed that women have a greater tendency than men to value helping people [55]. By having students work with a community partner to satisfy that partner's technologically based need, EPICS incorporates an altruistic component.

6.2.4 Team environment

The literature suggests women prefer team structures and smaller classes. Smaller class size is recommended to increase opportunities for participation [56]. Women may view teams as a place to form friendships [57] and teams can also function as a support group [58]; reliable support networks may contribute to the retention of women students [47]. Among African American and Latina students graduating in STEM fields, valuing group work in classes was an important factor in women developing positive self-concepts [59]. Consistent with this, the EPICS teams are self-selected teams ranging in size from 8 to 24 in each lab division paired with a common community partner. These lab divisions are further divided into project teams that are typically 4–6 students per project. The project teams work together within the lab divisions to support the needs of the community partner. Since students can self-select their projects and teams, they have some control over the group of students with which they will collaborate.

6.2.5 Alignment with EPICS

Although EPICS aligns with all of these characteristics and participants confirm that EPICS helps increase or reinforce their commitment to engineering, their primary reasons for being attracted to EPICS were not for the reasons above. However, these characteristics were present and important overall in the participants' experiences. Although the majority of the women in this study chose to participate in EPICS primarily as a means to get engineering experience, benefitting the community was the most important reason that two of the participants cited. In addition, other participants saw helping people as a benefit of participation in EPICS. Teamwork was also cited as a benefit of participating in EPICS although not a reason for enrolling in the program. As discussed previously, the participants described positive experiences related to working in a team environment, including learning from their peers.

Given that the literature surrounding women's career choices suggests that women tend to favor careers involving helping people or serving the community, it might be surprising that women would not choose courses supporting these preferences. However, the results of this study are consistent with work by Eccles and her colleagues, suggesting that women who choose engineering do not have greater altruistic motives than their peers. Looking at career aspirations for a number of high school students aspiring to master's or doctorate level degrees in health, physical science, engineering or math fields, Eccles and her colleagues [60] found that women interested in physical science, engineering and math placed less value than their peers on people- or society-oriented careers. Based on a follow-up of actual career choices in these same participants at age 25, demonstrated that actual major enrollment and/or career placement echoed the earlier aspirations; women choosing physical science, engineering or math career paths had lower people- or society-oriented career values [60]. Similarly, in a study examining CS students in comparison with non-CS students, Beyer and Haller [61] found that women CS majors were more similar to male CS majors than to non-CS majors with regard to attitudes towards CS, CS careers and work-life balance. Finally, in trying to understand how precollege students perceive engineering the National Academy of Engineering found that students do not think of engineering as a "helping field" [62]. Combined, this suggests that women might self-select out of engineering because it is not seen as a helping field and it therefore makes sense that women already enrolled in engineering might not be focused on helping people or society and might not enroll in EPICS to satisfy these needs. However, consistent with the NAE report Eccles suggests that increasing the number of women in fields such as engineering involves showing women how such fields can involve people and/or societal value orientations [60, 62]. Although participation in EPICS helps women see engineering as a helping field, it is not a primary reason the women cited for being drawn to EPICS. Interestingly, when women were asked how they would describe EPICS to another, they started with the benefit to the community.

6.3 Consistency with service-learning literature

The fact that women report increases in profession or disciplinary (contextual) knowledge and increases in persistence in college is consistent with literature on service-learning. Service-learning has also been linked to meeting ABET criteria with women and other minorities showing greater gains [63]. Astin and Sax [64] report that undergraduate participation in service contributes to positive gains in field or discipline knowledge and persistence in college. In a comparison of different types of service-based programs, Conrad and Hedin [65] found increases in self-esteem and career exploration in service-related programs. Gallini and Moely [66] report service-learning promotes greater academic engagement and retention among undergraduates. Increases in disciplinary knowledge and persistence intentions could also be related to the benefits women report regarding context for learning. Consistent with findings of the current study, research shows that service-learning experiences can increase perceived usefulness of the course materials and future intentions to use such learning [67] and increased ability to apply learning from one setting to another [68, 69].

7. Conclusions, limitations, and future research

This study has several limitations. First, it is a small sampling of students at one university. This is both a strength and weakness of qualitative research. While we can hear the voices of these eight students and describe their perspectives in great detail, generalization should be done with caution and with particular consideration for how these students might reflect the students in a different location. Second, this study represents the perspective of only women students and particularly of women students who choose to enroll in EPICS. While this was intentional by design, it precludes any gender-based comparisons. We have taken care to present our findings as outcomes from conversations with these women and not as a generalization across women or in comparison to men. Further research should include sampling men and also women who choose not to enroll in EPICS.

Therefore, from the results, we conclude that these women chose to participate in EPICS primarily because they were looking for an engineering experience. We also conclude that they believe their EPICS experience has had a positive impact on their commitments to engineering and that the team learning environment had a positive impact on their learning experience. These women saw EPICS as relating to the community and used the community context in their description of the program. They did not, however, cite this as a reason for them joining EPICS. These results help to prioritize the literature regarding women's experiences in engineering in understanding that gaining experience and increasing self-efficacy are very important motivations for women in engineering, and they cannot be ignored when considering the context. However, we cannot say the degree to which that is true or why the women choose EPICS as opposed to other opportunities to gain experience. Also, many of the characteristics of

EPICS that have been associated with attracting and retaining women—peer mentoring, small classroom environment, interactions with faculty—may impact retention more than influencing why women choose initially to participate in EPICS. To fully understand how EPICS impacts student learning experiences and persistence in earning engineering degrees as opposed to other educational experiences and opportunities, participants would need to be asked directly about these factors. This was beyond the scope of this study but we believe these are important questions that warrant future research.

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