

Exploring the Impact of Engineering Projects in Community Service on Students' Perspectives About Engineering as a Major

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Abstract—Engineering Projects in Community Service (EPICS) has been a structured program in engineering education curricula and pedagogies for almost three decades. EPICS aims to engage students with real-world and hands-on engineering practices while providing engineering solutions for the needs of communities locally and globally. Participating in EPICS helps engineering students develop their professional skills while applying their theoretical and technical knowledge towards a real-world service project. It also supports undergraduate engineering students' understanding of engineering practices and applications, thus positively impacting their professional formation as engineers. This paper explores how EPICS impacts engineering students' perspectives about their engineering majors based on their experiences in EPICS programs. A total number of 651 engineering students from various engineering majors and class standing responded to the end-of-semester survey. The survey was conducted in an EPICS program in a United States university during the academic years of 2019/2020 and 2020/2021. We conducted a thematic analysis of the student responses to an open-ended survey by inductive coding. They reflected on how their experiences in EPICS impacted their opinion of engineering as a major. Our findings showed that EPICS positively impacted most engineering students' thinking about engineering as their professional field. Some of the emerging themes included students developing a more nuanced understanding of real-world engineering applications, their professional and personal development, how to transfer theoretical knowledge into practice, engineers' impact on societies through projects, the connection between engineering and other disciplines, and developing a passion for engineering work. Understanding the impact of EPICS on students' perception of engineering itself can help us fully characterize the extent to which service-based programs affect students, thereby providing additional motivation to increase such programs' presence in undergraduate engineering education.

Keywords—student experience, service learning, impact of EPICS Introduction

I. INTRODUCTION

Accreditation Board for Engineering and Technology (ABET) establishes accreditation criteria for engineering programs, and they specifically define the purpose and nature of engineering design [1]. The engineering design process has

been taught in various ways in engineering education throughout courses such as first-year design courses, and EPICS is another way of teaching engineering design that also meets the requirements of ABET's program and student outcomes. Its uniqueness comes from connecting future engineers with communities and their needs [2].

EPICS is one of the experiential learning models that goes beyond traditional classroom settings to connect students with communities, and it was first established at Purdue University in Fall 1995 [3]. EPICS is a service-learning approach that connects students with communities, allowing them to apply classroom knowledge and integrate engineering design to meet local communities' needs through a multidisciplinary curriculum. In US higher education, there are over 30 universities that have implemented EPICS in their undergraduate and graduate engineering curricula [4]. EPICS projects provide solutions to the communities' needs that engineers should be involved in. To provide adequate solutions to communities, the students work as teams with various stakeholders such as faculty members, professionals in engineering companies, and community partners. While students learn throughout the design process, they also develop soft skills. To succeed in EPICS courses, students contribute to various dimensions of the design process, take responsibility for project management. Furthermore, they learn how to work as a team with diverse backgrounds and disciplines [2]. Overall, EPICS courses connect communities and future engineers while students professionally grow during their experiences and communities find solutions to their needs.

We focused on undergraduate engineering students' perspectives on how EPICS has changed their opinions of engineering as a major, if at all. The participants of our study actively worked in EPICS projects as teams, including various stakeholders. Exploring the impact of EPICS on students' perspectives about engineering as a major about their experiences in EPICS can give us an idea of how the current EPICS in engineering curriculum contributes to students' development in disciplines which is important to apply their theoretical and technical knowledge to real-world projects and to impact positively their professional formation as engineers.

In this study, we explored students' perspectives on the impact of EPICS on engineering as a major. The research question we aimed to answer is as follows.

RQ: How does participation in an EPICS program impact engineering students' perspectives about engineering as a major?

This study followed up on our previous study, where we explored the least favorite part of EPICS and the favorite part of EPICS for engineering students [2]. As a follow-up study, we positioned EPICS as an example of a course setting for service learning, which is considered an approach to experiential learning. Our study used Kolb's experiential learning as a theoretical foundation [5]. As per Kolb's theory, learning takes place as knowledge is acquired through experience and then applied to other comparable situations. Transferring knowledge to novel experiences involves essential stages such as reflection, conceptualization, and testing experiences that encompass the entire learning journey [6]. Similar to our previous study, we gathered and considered students' reflection responses on their EPICS experience to align with the reflection component of Kolb's experiential learning theory [2]. We thus leverage Kolb's model to understand the impact of the EPICS program, an experiential learning experience, on students' perspectives about engineering as a major.

The following sections introduce the research site, methods, findings, limitations, and conclusion.

II. EPICS IN THE RESEARCH SITE

Our study was conducted at a large public research university located in the southwest of the U.S. This institution has offered EPICS courses since 2009 [7]. The EPICS program accepts all students enrolled in their engineering programs regardless of their year in the college of engineering. EPICS coordinates project with domestic and international partners and has categorized these projects under four different themes: education, health, community health, and sustainability [8].

In our research site, EPICS is a one-credit course that students can take multiple times. The only requirement for the course is students must take it at least two semesters sequentially. Students choose their projects based on their interests in those four themes mentioned above. They have the flexibility to stay on the same project for multiple semesters or change their projects after each semester. They are required to work as a team in their assigned project teams, and the number of team members for each team varies from four to ten students. The faculty members assign students to team based on their project interests, class standing, their course schedule during that semester, etc. [9]. In addition, student teams are assigned an industry mentor with experience relevant to their assigned project.

Only students in their first semester of EPICS are mandated to participate in a 50-minute weekly lecture, in addition to their regular weekly team meetings. This supplementary lecture component serves the purpose of acquainting new EPICS students with the following key aspects: the course itself, encompassing its structure, essential

activities, and assignments; engineering design process; professional skills vital to their development, including project management, effective communication, and collaborative teamwork.

Moreover, students are guided on joining a new or pre-existing team associated with a real-world service project. As the course progresses, the focus shifts towards delivering relevant information in a timely manner to assist newcomers in successfully navigating their projects. This includes introducing them to the EPICS engineering design process, which serves as a scaffolding framework, offering structure to their approach to addressing project challenges. More detailed information about our research site, our course structure, and course expectations can be found in our previous study in [2].

III. METHODS

We used a thematic analysis approach to answer our research question [10]. We analyzed 651 responses at the end-of-semester survey for EPICS courses. Researchers used inductive coding by coding iteratively. First, Author 1 identified the initial themes and kept coding until no more themes emerged from the data. Then, Author 1 provided Author 2 and Author 3 with the initial codes. After they went through the data and the initial codebook to build their final codebook. In the final step, they finalized the codebook by agreeing on the themes and their definitions.

A. Data Collection

We collected end-of-semester surveys in an EPICS course in the 2019-2020 and 2020-2021 academic calendar years. During the 2020-2021 calendar year, the course modality was in a hybrid format due to the pandemic (COVID). While project teams met weekly via Zoom, the prototyping labs were opened, and students made reservations to work on their prototypes. When the pandemic spread to the US in the Spring 2020, the course changed modalities from in-person to online in March. Regardless of their year in their engineering programs, students could enroll in EPICS courses. Thus, the participants of this study varied from first-year to 5+ year undergraduate students from chemical, electrical, civil, mechanical, material science, industrial engineering, computer science, and other programs. A total number of 651 students responded to the end-of-semester surveys over the two academic calendar years. Students were asked, "Has your experience in EPICS had an impact on your opinion of engineering as a major?" and then, based on their Yes or No choices, they explained why it had an impact or not.

B. Data Analysis

We first cleaned the data and put all the responses in a worksheet. The data were separated into two groups that indicated "Yes" and "No". To answer our research questions, we used the thematic analysis method to observe the emerging themes [10]. For each group, Author 1 used an inductive coding method to identify the initial subcodes and group them for the emerging themes. The researcher iteratively read the students' responses until the emerging subcodes and themes were completed. Author 2 and Author 3 went through the initial subcodes and themes, and they provided feedback and

suggestions based on the data. All researchers worked on the codebook to merge these initial subcodes under emerging themes. They detected overlapping on some of the initial themes and they merged those subcodes. Finally, all researchers met and agreed on the final codebook, defined each subcode and provided two examples from students' responses for each subcode.

IV. FINDINGS

Students were asked a selected choice question: “Has your experience in EPICS had an impact on your opinion of engineering as a major?” First, students selected either Yes or No. Then, students who chose Yes were asked to explain how, and students who chose No were asked to explain why. Based on the survey responses, 86.5% of the students stated that EPICS had an impact on their opinions of engineering as a major, while 13.5% of the students stated that EPICS had no impact on their opinion (See Figure 1).

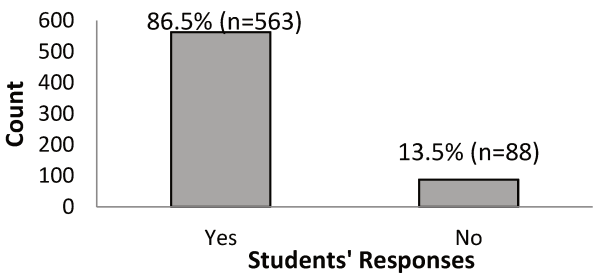


Fig. 1. The distribution of students' responses based on the end-of-semester survey question: Has your experience in EPICS had an impact on your opinion of engineering as a major? (Yes/No)

The responses for the reasons why EPICS had no impact on their opinions of engineering as a major (responses from students who said No) and how it had an impact (responses from students who said Yes) were analyzed separately. Table A in the Appendix shows the codebook analyzed by the researchers from the responses for both. In this section, we present the themes with examples that emerged from students' responses about how EPICS impacted and did not impact their opinions of engineering as a major. In the following two subsections, we only discuss the first three codes for each group. We acknowledge that we did not discuss all the themes that emerged from our study due to the limited space. We encourage the reader to check our codebook in the Appendix for the descriptions of our subcodes along with quotes from students' responses.

A. The Perceptions on the Impact of EPICS on Engineering as a Major

Students who stated EPICS impacted their opinions of engineering as a major explained how it impacted their responses. Researchers manually coded 563 responses. First, one researcher created the initial subcodes and merged them under themes. Then, two researchers went through them and suggested changes for the overlapping subcodes and themes. As a second step, the researchers met and created their final codebook. Overall, six themes emerged for how EPICS impacted students' opinions of engineering as a major. Figure

2 shows these themes: “Professional Development”, “Theory to Practice”, “Impact,” “Realizations,” “Broadening,” and “Gaining.” Each theme also has at least two sub-codes. In this section, we mention one subcode for the first three themes and provide students' responses for each subcode. The final codebook is shown in Table A in the Appendix.

Themes- The perspectives for impact					
Gaining	Professional Development	Theory to Practice	Broadening	Impact	Realizations
•Real-world experience •Confidence in major choice	•Teamwork skills •Presentation	•Application •Hands-on	•Insight •Knowledge	•In general •Communities	•Self-interest •Real-world design process •Connections between engineering and other disciplines

Fig. 2. The themes and their subcodes of how EPICS impacts students' opinions of engineering as a major

1) Gaining- real-world experience

We defined this theme as “gaining experience in real-world engineering practices.” Students work with community members, and they aim to develop their projects based on community needs. Therefore, they work on real-world projects and gain real-world experiences during the design process. Thus, some students indicated EPICS impacted their opinions of engineering as a major by practicing real-world engineering through projects. One of the students' responses to this subcode was as follows.

“I was able to get real experience and not just conceptual practice like in other classes. The stuff I did was real, and the lessons I learned were real.”

The students emphasized how their experience differed from their conceptual practice in classrooms and how the tasks and learning were “real.”

2) Professional development- teamwork skills

We defined teamwork skills as “how individuals gained teamwork skills through experience.” Students experienced the diverse opinions of other team members with different expertise and how they make decisions as a team and manage the tasks during the design process. One of the students emphasized the teamwork as the impact of EPICS on their opinions of engineering as a major as follows:

“It has really showed me what it is like to work for a real company and it has taught me a lot about teamwork and knowing that there are so many different types of people with different areas of expertise required for certain things.”

3) Theory to practice- application

We defined this subcode as “individuals learning how to apply their theoretical knowledge into practice.” EPICS is one of the service-learning experiences where they can apply their theoretical knowledge into practice, and students indicated having such an opportunity positively impacted their opinions of engineering as a major. They explored how they could apply their previous knowledge into practice during the design process. One student responded as

“I am able to apply what I am currently learning in the classroom to my project.”

We observe that students see their abilities to practice engineering by applying theory to their projects.

B. The Perceptions on No Impact of EPICS on Engineering as a Major

Students explained why EPICS did not impact their opinions of engineering as a major. Students were asked why EPICS did not impact their opinions of engineering as a major. 88 responses were manually coded by the researchers. We have three codes that emerged from students' responses. These themes are "The Past", "Deficiency", and "Unrelated to Major." The first two themes have three subcodes for each, while the third theme emerged without any subcodes. Figure 3 shows these three themes and their subcodes. In this section, we provided examples for each theme with one of their subcodes. Additional examples with subcodes and their definitions can be found in Table A in Appendix.

Themes- The perspectives for NO impact

The Past	Deficiency	Unrelated to Major
• Previous knowledge • Previous experience • Previous opinions	• Lack of new information • Lack of learning • Lack of Experience	

Fig. 3. The themes and their subcodes of why EPICS had no impact on students' opinions of engineering as a major.

1) The Past- previous knowledge

We defined the subcode "previous knowledge" as "An individual stating they already know what to expect from current experience." Some students stated their previous knowledge in engineering already helped them know what to expect during their EPICS course due to their previous experiences. Those experiences might be from their previous courses, curricular, and co-curricular activities. For example, one of the students stated that their experience in engineering clubs already let them know what they would be getting involved in when they are in engineering. Their response to the survey question was:

"I've done engineering clubs before so I think I knew what I was getting into when deciding on engineering."

Such previous experiences made students think that EPICS had no impact on their opinion of engineering as a major.

2) Deficiency- Lack of new information

We defined the lack of new information during the EPICS course as "not gaining new information through experience." Students thought that the lack of new information caused EPICS to have no impact on their opinions. One of the students briefly stated *"No new information presented"* as a reason.

3) Unrelated to major

This theme did not have any subcodes and we defined the theme as "their experience is not related to individuals' majors." Students were assigned to projects, and they did not have any tasks related to their majors during the design process. Thus, they thought EPICS did not make any impact on their opinions of engineering as a major. There may be several reasons why they were assigned to such projects that they were not able to relate their experience to their

engineering disciplines. One of the students stated their unrelated experience to their engineering major as follows: *"I have not done much related to my major at all, so I have not had a change of opinion."*

V. LIMITATIONS

We would like to acknowledge the possible limitations of this study. We aimed to explore how engineering students' perspectives on engineering as a major were impacted by EPICS, and we discussed the findings for engineering students. However, we cannot generalize our findings for all engineering undergraduate students who may participate in EPICS. Furthermore, students from non-engineering programs might have different experiences. We also acknowledge that the data included students who took the course before and during the pandemic. Therefore, we cannot claim how the change of course modality impacted students' perspectives on how EPICS impacted their opinions on engineering as a major. However, we believe that their responses to the end-of-semester surveys reflected their perspectives based on their experiences. We would not know how seriously they took the survey, but we assumed that they were transparent while responding to our survey questions.

VI. CONCLUSION

We used thematic analysis to explore students' perceptions of how EPICS impacts students' opinions of engineering as a major. While we acknowledge how important the impact of EPICS in communities is, it is also crucial to understand the impact of EPICS on our future engineers' opinions. Most of the students indicated that EPICS has a positive impact on their opinions of engineering as a major. Understanding how EPICS impacts students' perception of engineering itself can help us fully characterize the extent to which service-based programs affect students, thereby providing additional motivation to increase such programs' presence in undergraduate engineering education. The impact of EPICS on engineering as a major may affect the engineering students' success, effort, and motivation in their profession. Teachers and researchers may consider enhancing the structure and content of EPICS in engineering curricula to change the no-impact perceptions into positive impacts.

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APPENDIX

TABLE A. THE CODEBOOK OF THE STUDENTS' RESPONSES

Yes/No	Code	Subcode	Initial definition	Examples_1	Examples_2
No	The Past	Previous Knowledge	An individual stating they already know what to expect from experience	<i>I sort of knew this might be what it's like.</i>	<i>I've done engineering clubs before so I think I knew what I was getting into when deciding on engineering</i>
		Previous Experience	Experiences prior to the current experience	<i>Done team-projects like this before</i>	<i>After participating in it last semester my views haven't changed.</i>
		Previous Opinions	Opinions students already had before they experienced	<i>I already enjoyed engineering as a major and epics just strengthened that.</i>	<i>Gunna be an engineer regardless</i>
	Deficiency	Lack of new information	Not gaining new information through experience	<i>No new information presented</i>	<i>I didnt feel like i got much out of it</i>
		Lack of learning	Not learning anything new	<i>This class didn't have much impact, I enjoyed it and did learn about teamwork and the design process. But it didn't teach me anything new about engineering</i>	<i>Didn't feel like I learned much from it. We didn't even have an actual class</i>
		Lack of experience	Not experiencing anything new to an individual	<i>Unfortunatley, it was hard to reach our community partner so i don't think we got the best experience of EPICS</i>	<i>Didn't really get to the point where we did any engineering due to not having a community partner until the last two weeks so it was mostly just research.</i>
	Unrelated to major		Their experience is not related to individuals' majors	<i>I have not done much related to my major at all, so I have not had a change of opinion</i>	<i>My Epics project had nothing to do with electrical engineering</i>
	Gaining...	Real-world Experience	Gaining experience in real world engineering practices	<i>I was able to get real experience and not just conceptual practice like in other classes. The stuff I did was real, and the lessons I learned were real.</i>	<i>Because I've had such a positive experience in EPICS, I am more comfortable with my choice to pursue engineering as a major and as a career.</i>
Yes		Confidence in major choice	Earning confidence in engineering practices by experience	<i>Yes; I am more confident that CS is for me.</i>	<i>I have more confidence that I chose the right major.</i>

	Professional Development	Teamwork skills	How individuals gained team-work skills through experience	<i>It's helped me improve my teamwork skills and gain project experience working on a team.</i>	<i>It has really showed me what it is like to work for a real company and it has taught me a lot about teamwork and knowing that there are so many different types of people with different areas of expertise required for certain things.</i>
		Presentation	How individuals gained presentation skills through experience	<i>It really put into perspective how important documentation and presenting is. People view engineers as somewhat uncharismatic, however I think that that skill is actually very important to being a successful engineer. Presenting in this class was a valuable experience for me.</i>	<i>Learnt team working and presentation skills along with technical skills.</i>
	Theory to Practice	Application	Individuals learning how to apply their theoretical knowledge into practice	<i>I am able to apply what I am currently learning in the classroom to my project.</i>	<i>I am able to apply concepts that I learn in class to my projects.</i>
		Hands-on	Individuals learning through hands-on projects	<i>This class has validated my choice. Being able to work hands on with projects has confirmed my interest and desire to continue on the Engineering track.</i>	<i>Yes, EPICS has given me hands on experience that has made me even more interested in engineering</i>
	Broadening...	Insight	Expanding one's insight in engineering disciplines	<i>Yes, it showed me that there is more than just what I originally thought for computer science as a major.</i>	<i>It has made me realize how much there is to engineering beyond simply solving a problem. There is a lot of planning involved.</i>
		Knowledge	Expanding one's knowledge on engineering topics	<i>EPICS has helped me see many of the practical implications of my major, and the specific project I am on in particular has expanded my knowledge on many chemistry topics, something I am truly grateful for.</i>	<i>It has broadened my knowledge of the many avenues engineering can lead to. Provided first-hand experience of what working as an engineer will be like.</i>
	Impact	In general	Impact of engineering from a broad perspective	<i>Has helped me see the everyday impacts of engineering</i>	<i>Gave me some ideas about how I can make an impact regardless of what engineering major I am</i>
		Communities	Understanding how engineers make an impact in communities	<i>It has definitely brought me to think more about how I can impact my community and not just the medical field.</i>	<i>Being able to give a community member a final deliverable after working on the project for weeks results in relieving feelings. However, seeing first hand how the deliverable positive impacts the lives of said community members makes all the work worthwhile, and that is something that I would like to experience in my career.</i>

	Realizations	Self-interests	Realizing their self-interest in engineering field through their experience	<i>EPICS has made me more excited about being an engineer. Through EPICS I have realized that I really enjoy the design process.</i>	<i>It showed that I am really passionate about engineering and pursue it as my career.</i>
		Real-world design process	Realizing how the design process works in reality	<i>Made me realize that it's okay not to get the correct product the first time and to keep working on it until it eventually works</i>	<i>It showed me how the engineering design process truly works</i>
		Connections between engineering and other disciplines	Seeing the connection of engineering with their fields	<i>I did not the purpose of business/entrepreneurial aspects had anything to do with engineering, but now I see. For this, I see engineering with clearer eyes.</i>	<i>I definitely now see the business aspect of my major and how I can use my skills to hopefully make a business in the future. I feel like I got a taste of what it is to start something on my own and to see how far it goes.</i>