Student Learning in Computing-Based Service-Learning

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***Abstract*— This Innovative Practice Full Paper presents an approach to computing, project based service-learning. Service-learning, also called community-engagement and community-based learning, strives to mold students into lifelong learners who are mindful of their communities and the world around them by developing their critical thinking capabilities and helping them acquire knowledge to aid them in understanding the world. Although service learning is not new to computing curriculum, literature and resources are scarce. At Purdue University, the Engineering Projects in Community Service (EPICS) program offers service-learning design courses to undergraduate students from many disciplines. This study focuses on students engaged in software-based projects. An analysis of the reflections from three project teams show that students are learning through the design process, value the mentoring within the team and the impact of their community partners on themselves and their view of their profession.**

Keywords—computing, service-learning

I. Introduction and Background

Service-learning is a pedagogy that integrates engagement with local or global partners with academic learning. Hatcher and Bringle defined service-learning as:

> …a credit-bearing educational experience in which students participate in an organized service activity that meets identified community needs and reflect on the service activity in such a way as to gain further understanding of the course content, a broader appreciation of the discipline, and an enhanced sense of civic responsibility. [1]

The principle of engaging with community partners as equals in reciprocal partnerships has motivated some to use terms such as community-engagement and community-based learning to move away from the term "service" and the vertical relationships that the word implies. These terms are used at different institutions to reflect the same pedagogy. There is not a consensus on the use of the terms. A recent discussion thread on the U.S. Higher Education Service-Learning listserv reinforced the mixed opinions on the terms, and recognized that the term service-learning can and still does reflect the ideals of the pedagogy. Therefore, the term service-learning will be used in this paper.

Service-learning strives to mold students into lifelong learners who are mindful of their communities and the world around them by developing their critical thinking capabilities and helping them acquire knowledge to aid in their understanding of the world. This is done within the context of learning disciplinary skills and connecting the disciplinary learning to the broader awareness of their use and place in society. Service-learning is well-established in many disciplines in higher education [2].

Engineering and computing have been slower to adopt the pedagogy, but there has been a steady increase in examples of courses and programs over the last two decades [3-5]. Research in engineering education is also growing on the impact of service-learning on our students, faculty and alumni in engineering [6-9].

In computing, there are fewer examples published and little research on the impact of the pedagogy. Some of the engineering programs include computing, such as the EPICS Program at Purdue University [10] and their study of alumni included computing professionals [6]. Examples of computing-based service-learning were described in the IEEE volume *Service-Learning in the Computer and Information Sciences* [11]. Other examples include Villanova University, where computing service-learning is a supplemental experience outside a student's program of study. The opportunity is more of an internship than an actual course integrated into the curriculum. Students are either involved in getting paid to create a website or are sent to schools to teach other students about topics focused on computing. This opportunity is limited to students of the same discipline and there is no discussion of the learning impact of this pedagogy on the students [12].

At the University of North Carolina at Asheville, the computer science department developed a mobile computing application that enables students to take the concepts they learned in class and apply them to creating technological applications for the community. The mobile application is implemented through three courses. The frontend (user interface) and backend (the logic and data storage) of the mobile

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application are completed in two courses the first semester, and the integration and testing are completed in the second semester. This opportunity is also limited to students of the same discipline and the same academic level. Also, although the goal is to empower students, there is no clear discussion on the learning impact of this pedagogy [13].

This paper provides an example of successful computing-based service-learning that incorporates multi-disciplinary and varying academic levels of students. This paper also examines the learning impacts of the pedagogy as perceived by the students through their reflections. The context studied involves students focused on computing as part of a larger multidisciplinary service-learning program, called EPICS.

The EPICS Program

The EPICS program at Purdue University offers service-learning design courses in which multi-disciplinary teams develop technological solutions that solve community needs. The EPICS program provides students with real-world design experiences so they can learn how to work as a team; communicate with a client; design, develop, and deploy a product; and experience firsthand the real impact they can have on our local and global communities. A human-centered design process guides the students to remain focused on stakeholders through the multi-semester and at times, multi-year EPICS projects. According to Zoltowski, Oakes, and Cardella, "user-centered design focuses on the end-user of the product, whereas human-centered design considers the stakeholders more broadly than the stereotypical user" [14].

There are approximately forty class sections of EPICS each semester. Each section contains ten to twenty-five students that are split between different projects, typically three to five projects per section. EPICS is vertically integrated, which means first-year to senior level students can take the course and work together on the same project.

Originally, the EPICS model formed sections based on a community partner where all of the projects in that section were done for that same partner. However, based on student and community partner feedback, dedicated sections for computing were created. Most of the non-profit partners had a computing need. Therefore, bringing those needs into a common section allowed the program to focus software expertise to better mentor students and enabled solutions to be shared across partnerships more effectively. The computing teams are formed around common software technologies such as database applications, web development, iOS and Android development, etc. Since the formation of these new software oriented teams, no formal research examining student performance has been completed. Focusing on software design projects in the EPICS program, this paper will explore how students perceive their performance on these software oriented projects, and gauge the importance of vertical integration, multi-disciplinary teams, and engaged community partners. We have one main guiding research question and three sub-questions:

1. What do students perceive they are learning from computing-based service-learning?
    a. What is the impact of a real community partner?
    b. What is the impact of vertical integration?
    c. What is the impact of multi-disciplinary teams?

II. Methodology

A key part of the pedagogy of service-learning is reflection [15,16]. Reflection has also become a more widely used learning tool in engineering education as evidenced by the Consortium to Promote Reflection in Engineering Education [17]. The EPICS program uses reflection in several ways [18]. In the EPICS program, each student writes a weekly reflection in an electronic notebook that is kept in Microsoft OneNote on a common server, and is accessible to instructors and teaching assistants. At the end of each semester, EPICS students are asked to submit a final reflection that is designed to be a summative look at their experience and learnings for the entire semester. They are asked to critically reflect on what they learned by choosing two of these topics:

1. Personal and Professional Development: What did you learn about who you are (your strengths, weaknesses, assumptions, skills, convictions, etc.) and who you want to become, personally or professionally?
2. Social Impact: What did you learn about the broader impacts of your work and how you and others can affect change locally and/or globally? What did you learn about the community, the needs, and/or the quality of the service provided?
3. Academic Enhancement: What did you learn related to your discipline and how was that enhanced by the service-learning context? What did you learn about Human-Centered Design?
4. Ethics: What have you learned about professional ethics, the ethical issues you encountered in your team and your project, and how decisions regarding ethical issues are made individually and as a team?

The EPICS uses a model for reflection that was developed by Ash, Clayton and Moses [16] that asks students:

1. What did you learn?
2. How did you learn it?
3. Why does the learning matter?
4. What will/could you or others do in light of this learning?

Students choose from two of the optional topics and answer the four reflection questions for both topics.

The final reflections from one software oriented section with 15 students were evaluated for this exploratory study. The section studied had three software projects. The projects included the following:

1. Project 1: iOS application designed to keep track of student progress and the facility's resources at a therapy camp for children with disabilities.
2. Project 2: iOS application to help students learn how to spell using an American Sign Language (ASL) search function at a school who works with deaf or hard of hearing children.

3. Project 3: iOS application that helps deaf or hard of hearing students communicate with parents who do not know ASL. This project is being developed for the same school as project 2.

Students were placed on one of the three projects based on their expertise, grade level, preference and needs of the team. Ideally each project team should be comprised of students with a mix of complimentary skill sets and be a mix of first-year to senior level students, with at least one student with strong software expertise. This helps balance the team between learning and implementation, so that although there will be members who are learning most of the time on the project, there are also students with expertise who can push the project forward. The following is the team make-up of each project with students' names replaced with pseudonyms per the university's IRB protocol:

TABLE I. TEAM MAKE-UP OF SOFTWARE ORIENTED SECTION IN EPICS

Project	**Team Make-up**		
	Student Pseudonym	***Level***	***Major***
Project 1	Carlos	4th Year	Electrical Engineering
	James	4th Year	Electrical Engineering
	Carla	First-Year	First Year Engineering
	Andrew	First-Year	First Year Engineering
	Tim	First-Year	First Year Engineering
Project 2	David	4th Year	Computer Engineering
	Peter	4th Year	Computer Engineering
	Sue	First-Year	First Year Engineering
	Jorge	First-Year	First Year Engineering
	Juan	First-Year	First Year Engineering
Project 3	Charlie	First-Year	First Year Engineering
	Mark	First-Year	First Year Engineering
	Jack	First-Year	First Year Engineering
	Mary	2nd Year	Mathematics
	Tom	First-Year	Industrial Technology

Each student's reflection was coded independently and analyzed for common and contrasting themes using an inductive thematic analysis [19]. The fact that the students are given choices on what to write about and freedom to explore the areas that are of most meaning to them makes the data a rich source of their perspective on their learning and experience in the course.

All of the reflections were read by the researcher and common themes emerged from the data set of the reflections. The themes were developed, and then all of the reflections were coded for these themes and example quotations were identified. The themes and quotations were reviewed by the co-author as a check in the process and compared against literature for similar studies.

III. RESULTS

Five themes emerged from the inductive thematic analysis of students' final reflections. These themes were:

1. Peer-to-peer mentorship
2. Teamwork and collaboration
3. Impact and motivation
4. Learning (and gaining confidence in) technical and professional skills
5. Human-centered design

Each of these themes are briefly described and discussed with example quotations.

A. Peer-to-Peer Mentorship

The vertical integration or mixing of students from different academic years provides the opportunity for students to engage in peer-to-peer mentorship. Upper division students bring skills and knowledge learned in previous academic courses and experiences that enable them to be ideal mentors to students beginning their undergraduate careers. In EPICS, students can return to the same team for multiple semesters, and there is an explicit expectation that they will mentor new students during the transition. An opportunity to be mentors of the team helps solidify an upper division student's growing expertise and develops their mentorship and leadership skills. As stated by James, a senior level student:

> I feel like my role as design lead was amplified due to having three first year engineering students in our group. It gave me an experience similar to being a manager for a design project in the industry. The path was not always smooth or stress free and that is what allowed me to really test and strengthen my leadership skills.

Although the experience sometimes added complexity to the learning experience, students were able to see how the mentoring experience benefited them.

While upper division students benefit from developing their mentorship and leadership skills, lower division students benefit from having peer mentors who guide them in learning new knowledge and skills. Lower division students form views about themselves and their future careers by working with upper division students who lead by example and motivate their lower division peers. A first-year student, Tim, exemplified the theme of aspiration and mentorship in his statement about working with two senior level students, Carlos and James,

> Even if I don't end up being these exact people, I aspire to be close enough to be that good at what I do end up doing.

Discussions about peer-to-peer mentoring was not uniform across the project teams. Most of the discussions about peer-to-peer mentorship came from one team that did not have an engaged community partner.

B. Teamwork and Collaboration

The significance of teamwork and collaboration was cited by several students and has been a theme cited in previous research on EPICS [14]. Specifically, the students discussed

how the success of a team was based on how well they worked and collaborated together. As stated by Carla:

> Our team will not excel without each and any one of them. I learned that being in a team, you have to respect each other in order to excel. The importance of working together and doing our parts determine the level of execution of a team.

Therefore, students realize the value of teamwork, and attribute the success of a project to working together as a team.

The teams were comprised of students from four different majors. Within these multi-disciplinary teams, students realized how working with others from different backgrounds brought unique insights to the team. As detailed by Andrew:

> The importance of phenomenal team members was a lesson I quickly learned when being engrained into this group. Each and every single one of us took the project and ran with the idea, eventually all becoming extremely important components with each one of us carrying our specific niche within a group.

Students realize the value of everyone's unique forte in the group, and how their skills complement each other in making the project a success.

C. Impact and Motivation

The theme of impact and motivation emerged specifically when students were talking about their community partner who receives the results of their project when completed successfully. Two of the three projects had a very engaged community partner, and one was not engaged during this semester. On the two teams with engaged partners, nine out of ten of those students chose to write about how engaging with the community partner encouraged them to work hard. The students were able to understand the needs and realize firsthand the impact they would have on the specific community need. As stated by Sue:

> During the midterm design review, we received a lot praise for continuously communicating with the community partner. Our constant communication with [community partner] is one of the reasons we moved along so quickly this semester.

Hence, students attribute the rapid progress of the project to constant communication with their community partner. Other students saw the opportunity to make a difference and this increased their motivation. As stated by Juan:

> One other thing I also learned was how gratifying it is to be working with a project partner who truly cares about the work that I am doing. I learned this when we visited [community partner's facility] I was able to really talk to [community partner] for the first time. I could tell she really cared about the work we were doing on the project and that she was as excited as we were to be making progress on the app. Being at [community partner's facility] and seeing the community that we were helping also gave me inspiration to work harder because I wanted to genuinely contribute to a worthwhile goal for a great community.

This statement exemplifies how students are influenced by their community partner and the need to make a difference in the lives of others.

Some students brought attention to how the work engineers and other professionals do could have a negative impact. As stated by Peter:

> Suppose some non-profit organization wants to develop an app for charity to do exactly what we are doing, since our patent exists, they would have to stop making the app which would only hurt society. In light of this, others could be cautious to patent something very quickly unless they're certain they want to either use that idea to contribute to society or to build a business off of it, otherwise they would simply be stopping others from doing that for no good reason.

Therefore, students are realizing the impact professionals in their fields can have on society, and thinking about how decisions regarding ethical issues impact society.

D. Learning Technical and Professional Skills

Many students addressed the technical software and professional skills they learned and solidified while working on computing service-learning projects. Some students focused on discussing the specific new skills and tools they learned. For example, Carlos stated:

> Throughout the course of this semester I learned a lot about designing server applications and interacting with servers from mobile applications.

Therefore, even senior students are learning new technical software skills like designing server applications and learning how mobile applications interact with servers. Some students discussed the confidence and reassurance they gained from learning new software skills and tools. For example a first-year student detailed how with every success, she gained more confidence in her abilities. The student, Carla, stated,

> I remember how happy I was when I succeeded in changing the font size of a page on the application.

Later in her reflection, Carla continued to describe her experience by noting that:

> The learning process was a challenge, but a lot of fun as well. You have this feeling of pride when you finally did something correct. I learned that you get the best feeling when you succeed after failing multiple times.

These statements, especially from the first-year students, show a growing confidence in their own abilities with the mentoring and support from the upper division students. The confidence also showed up in the reflection from a senior student, David, who stated:

> When entering this semester, I had only had one semester of an internship under my belt. As a software engineer that made me nervous. I want to feel like I'm good at what I do, but often would overthink and just point out the things I did

> wrong. My one semester in EPICS has added confidence to who I am as a software engineer.

Regardless of the student's level, students gained confidence in their abilities to develop software as they learned new skills and/or applied the knowledge they learned in previous courses.

Other students talked about the importance of project management and planning. As stated by James:

> Also from this experience I learned the true value of planning. From planning prototype mock-ups to project timelines. An accurate timeline can be essential to staying on track and prototypes will focus and refine ideas before implementation. All these lessons will be valuable assets in working through problems in my future career.

Students are learning the value of project management and planning by working on a real-world project and experiencing the results of strong and weak planning.

Communication skills, both oral and written, were also cited as skills that were developed. One student discussed how his leadership position helped him develop a better appreciation for presentation skills. As stated by Charlie:

> I also developed better communication skills through being a Design Lead…The biggest thing I learned was how to present in front of a professional audience. The design reviews exposed me to leading professional presentations. I learned that it is important to practice presentations a lot before presenting them. I also learned the importance of organizing presentations so that the flow is not confusing and distracting.

Therefore, not only are students learning technical skills to implement a solution, but they are also learning the broader professional skills needed in today's global economy, including how to communicate their ideas and designs to audiences of varying backgrounds.

E. Human-centered Design and Customer Awareness

Learning human-centered design was another theme that emerged from the student reflections. Human-centered design is a central theme of the EPICS program and all students go through four introductory sessions on the topic. In human-centered design, stakeholders are considered more broadly than the stereotypical user [14]. Some students discussed how they learned the importance of engaging with their stakeholders to gain feedback regarding their designs. As stated by Jorge,

> The focus on what the user wants and the prevalence of user-feedback I feel are core ideas to this design process which I will be able to utilize throughout my career.

Students realize the importance of human-centered design not only for their current projects, but also for their future professional careers. A key part of human-centered design is the interaction with a user and/or stakeholder. Sue went into detail about how communicating with their community partner assisted them in moving forward through the design process.

> We made a very simple prototype during the specification development phase to get approval from [community partner] on our general ideas. Next, we made an interactive mock-up during the Problem Specification Phase. We also used feedback from a focus group to improve our mock-up. I will use my experience with mock-ups to benefit me in the future. Prototypes are a great design tool to show the community partner where you are at in the design process.

Students gather input from their stakeholders in order to make design decisions and progress on the project. They are also learning design skills that help them communicate their ideas to their stakeholders in order to receive valuable feedback.

Interestingly, the students who discussed human-centered design were from the two teams with engaged partners. None of the students from the team with an unengaged community partner discussed human-centered design.

IV. DISCUSSION

This exploratory study examined the final reflections from 15 students working on software projects for real community partners. A single section was chosen to limit the variations in experience and therefore, clearly limits the generalizability of the findings. Even within that constraint, several interesting finds arose. Students discussed their development of teamwork, leadership and professional skills that are consistent with previous findings from the broader program. There was not a significant difference between the software projects and other engineering experiences in EPICS.

Students articulated their own development of the technical skills as well. Their experiences included student discussions about their own self-confidence working on the projects. Self-efficacy has been cited in the literature as a factor contributing to retention in engineering and computing. Therefore, since computing service-learning projects help students see their ability to succeed in computing, these service-learning projects could play a major role in retention in computing programs.

Each of the three projects offered had a different community partner. One of the three had challenges in the semester studied and therefore, had minimal contact with the students. The contrast between the two projects with frequent contact and the one without was significant. The engaged partner exuded the following attributes:

1. Actively participating by providing feedback to students,
2. Promptly replied to emails sent by students,
3. Showed genuine interest in students' work,
4. Passionate about their own work.

Almost all of the students who worked on the projects with engaged community partners chose to talk about how interacting with their partner influenced their views and gave them motivation to work harder. Based on the student reflections it is evident that they had begun to empathize with their community partner and stakeholders, and designed with them in mind. Students also witnessed firsthand the impact they were having on their community, and began to connect how, as future professionals, they have a social and ethical responsibility to society.

Students partnered with an engaged community partner also developed an understanding of human-centered design and the value of involving stakeholders throughout the entire design process. The students saw value in the feedback they received, and realized how designing with stakeholders in mind helps progress the project quicker in the right direction.

Interestingly, none of the students who had an unengaged community partner talked about impact or human-centered design. Instead, those students chose to focus on the value of peer-to-peer mentorship. In fact, four out of the five students on the team talked about peer-to-peer mentorship. This team was ideal for peer-to-peer mentorship because the make-up was two fourth-year students with software expertise and three first-year students. The vertical integration of the team provided a scaffolding for the younger students and opportunities for leadership for the upper division students. Therefore, although their community partner did not influence them in terms of motivation or provide continual feedback on their designs, the students relied on each other to stay focused and motivated, and progressed the project forward.

Evidence from the summative reflections shows student perceptions of learning across a broad spectrum of learning outcomes. The learning outcomes include:

1. Understanding human-centered design as a start-to-finish process and applying the process to solve any real-world problem;
2. Applying material from their discipline and acquiring new knowledge to solve real-world design projects;
3. Awareness of the customer, and designing with stakeholders in mind;
4. Working on a multi-disciplinary team and appreciating the contributions from individuals of varying disciplines;
5. Awareness of professional ethics and ethical responsibility, as well as an appreciation for the role their discipline has on society and their social responsibility.

The perceived learning by students was validated by the observations of the instructional team for that section. The findings were consistent with their observations.

Future work can expand the analyses of the reflections across multiple divisions and comparing software teams with other engineering disciplinary focused teams. Other data is also available, including weekly reflections, design reports and the projects themselves that could be triangulated with the summative reflections.

CONCLUSION

The context of the service-learning, multidisciplinary teams and vertical integration offered a rich learning environment and are well suited for computing education [11]. The multi-disciplinary and vertical integration aspects replicate the real-world more realistically. As future professionals, these students will work with other professionals who will be of varying disciplines and levels. Therefore, the knowledge and skills gained from working within these vertically integrated and multi-disciplinary teams is significant for their future careers. Also, the impact of the community partner was very evident and identified as one of the most significant parts of the experience for teams with a partner who was regularly engaged. An engaged community partner provided the human element to human-centered design. This human element helped exemplify to students that computing impacts our communities and society as a whole. This example is significant because as future professionals, and possibly future software developers, what they design and develop have implications on our world, and it is important they are aware of their social and ethical responsibilities. Although one of the project teams had a negative experience with their community partner, it is important to realize that this is reflective of the real-world. Although the partnership with the unengaged community partner was later terminated, during the semester, the instructors used it as a learning experience for the students. As future professionals it is important they learn how to deal with real-world customers who will not always be ideal. From this experience students saw the value of teamwork, leadership and peer-to-peer mentorship. Ultimately, the learning impacts of the pedagogy as perceived by the students through this exploratory study illustrate that these kinds of experiences could be a benefit in the suite of experiences for computing students.

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