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Collaborative Project-Based Service Learning: What Motivates Students to Participate and What Do They Value After?*

DENIZ DOGRUER
2600 Tenth Street St. 308, Squishy Robotics, Berkeley CA 94710, USA. E-mail: denizdogruer@berkeley.edu

VIVEK RAO
2220 Piedmont Ave, Haas School of Business & Department of Mechanical Engineering, University of California – Berkeley, Berkeley CA 94720, USA. E-mail: vivek.rao@berkeley.edu

ALICE MERNER AGOGINO
230 Hesse Hall, Department of Mechanical Engineering, University of California – Berkeley, Berkeley CA 94720, USA.
E-mail: agogino@berkeley.edu

Engineering design pedagogy has increasingly integrated project-based service learning (PBSL) across the curriculum for its promise of greater engagement of students, transfer of desirable skills, and improved student retention and persistence in STEM. However, little is understood about how student motivation for engaging in PBSL aligns with the actual perceived value that students derive from PBSL experiences. In this work, we examine three years of an engineering design course integrating a core PBSL element representing 70 participants and 17 projects, using a mixed-methods qualitative approach to ascertain student motivation, goals, and perceived value at four junctures before, during, immediately after, and 1–3 years after the PBSL experience. Our findings indicate that while students appear motivated to pursue PBSL experiences because of their desire to create positive impact, the sustained value they derive from PBSL experiences is primarily about career clarity and design process understanding. These results have important implications for how engineering educators present PBSL experiences to students, how they are positioned in a curriculum, and how they operate in conjunction with other efforts to promote retention and persistence in STEM.

Keywords: design pedagogy; Project-based service learning (PBSL); experiential learning; social impact; student motivation; perceived value

1. Introduction

The evolving engineering work environment requires engineers to have practical ingenuity, creativity, communication skills, high ethical standards, a strong sense of professionalism, leadership, business and management skills in addition to technical engineering skills and knowledge. Design pedagogy increasingly plays a central role in realizing and instilling such outcomes among STEM students [1–3]. Design pedagogy is widely delivered through experiential courses [4, 5] to develop innovation capacity through project-based learning (PBL) [3]. Within PBL, project-based service learning (PBSL) is "a form of active learning where students work on projects that benefit a real community or client while also providing a rich learning experience" [6]. PBSL opportunities have been increasingly integrated within undergraduate engineering education [7], [8] both as curricular and extracurricular activities; however, less so in graduate education [5]. Studies have shown that PBSL opportunities promote students' technical skillset development and professional skillset development [8–10], while also increasing recruitment, retention, and diversity [6, 9].

However, challenges implementing PBL opportunities in engineering education are well documented and reported to exist on multiple levels: individual, institutional, and cultural [11]. Most relevant to this research are instructor difficulty in facilitating student teamwork [12], students' lack of teamwork skills [12, 13] and a lack of learning motivation [14].

Among these challenges, the role of motivation in learning and cognition [15–17] and the role of motivational constructs, such as goals, values, self-efficacy, and beliefs, as important variables in improving student learning outcomes [16] has been widely studied. Many examples of scholarship have described how motivation is important in experiential learning in STEM, including chemistry laboratories and engineering design [18, 19] and how student motivation can be a driver for choice, persistence, and performance in engineering [20, 21]. In this work, we explore students' motivations to pursue social-impact driven, project-based service-learning opportunities, how these motivations evolve over the course, and ultimately what students value at the conclusion of the course. These lead to three research questions:

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R1. What motivates students to pursue design project-based service-learning experiences and what outcomes do they seek from such experiences?
R2. How do student anticipated benefits (i.e., motivations, goals, perceived value) evolve over the course of a PBSL experience?
R3. What outcomes do students perceive as most valuable at the conclusion of a PBSL experience?

To explore these questions, we consider related work on motivation and PBSL (Section 2), introduce research methods (Section 3) and discuss results (Section 4) and their implications (Section 5).

2. Related Work

2.1 The Role of Motivation in Engineering Education

The role of motivation in learning and cognition has been widely studied [15–17]. Student motivation can serve as a driver for choice, persistence, and performance in engineering [20, 21]. Two common time scales, short-term tasks and long-term goals, have driven researchers to better understand the connection between students' motivations to present engineering tasks, such as problem solving, to their future goals [20].

To better understand the interplay between learning outcomes, student motivations and perceived value of engineering students who partake in engineering design, capstone and service-learning courses, researchers have employed a variety of methods exploring student self-report data. Research methods utilized range from quantitative methods deploying surveys to collect self-report data to measure engineering self-efficacy and persistence in engineering [21] to qualitative methods utilizing interviews and student reflections [20, 22]. Sequential mixed methods approaches have also been utilized. Examples of sequential mixed methods include utilizing of quantitative surveys to inform and motivate further exploration through qualitative follow-up interviews [10, 23]; as well as the use of qualitative interviews to inform the development quantitative surveys [24].

In this work, we use a mixed-methods qualitative approach to understand student motivation at various touchpoints in the PBSL experience via surveys and interviews. Our work draws on methods similar to Mamaril et al. [21] and Norback et al. [22]. We extend on existing findings by (1) understanding student motivation *before* the PBSL experience, and (2) understanding the difference between students' motivating reasons to join the class and their perceived value of the experience afterwards.

2.2 Project-Based Service Learning

Project-based service learning (PBSL) is "a form of active learning where students work on projects that benefit a real community or client while also providing a rich learning experience" [25] and are increasingly common in engineering education. For example, EPICS (Engineering Projects In Community Service), a national program available at several universities, pairs non-profit organizations as project partners with student teams to design solutions for local communities [7]. PBSL is also very common in capstone design courses in which projects are sourced from local clients, international communities, and projects related to Engineers Without Borders (EWB) and other service organizations.

Typical outcomes measured and reported for PBSL programs include changes in (1) knowledge and skills; (2) attitudes and identity; (3) recruitment, retention, and diversity; and (4) professional performance. Common assessment methods for measuring outcomes include reflective essays, surveys, and journal entries. In a review of PBSL experiences, Bielefeldt et al. [25] found that PBSL improved retention in engineering students and that the voluntary participation in PBSL opportunities of women engineering students was higher compared to their representation in engineering overall. Additionally, in a survey asking students to compare their service-learning experiences with their traditional coursework-based learning experiences, students reported 45% of their technical skill learning and 62% of their professional skill learning was acquired through their service learning opportunities. Furthermore, women engineering students reported service-learning opportunities as the source of the technical and professional skills significantly higher when compared to male students [9].

The majority of research on PBSL represent undergraduate students' experiences; PBSL in graduate education is less well-understood. One example of combining graduate education with PBSL is the case study documented by Talbert et al., describing the implementation of a structured PBSL course that replaced a Masters' thesis requirement [5]. Graduate students in this structured PBSL course worked with non-profit organizations and provided the project sponsor with a final report. With approval from the graduate committee, the final report was submitted in lieu of a master's thesis.

The adoption and implementation of PBSL opportunities, and Project Based Learning (PBL) opportunities more broadly, does not come without challenges and barriers. A literature review of 108 research articles published from 2000–2019 exploring the implementation of PBL in engineering education reported challenges existed on multiple levels – individual, institutional, and cultural [11]; specific challenges include difficulty in facilitating student teamwork [12], lack of student teamwork skills [12, 13] and a lack of learning motivation [14, 26] which is a particularly salient challenge. To address the sensitivity of PBSL success to motivation, Jones et al. identified several instructional elements as that affect student motivation in PBL courses [27]. The authors report these motivating opportunities could both foster and hinder student engagement, emphasizing the need and value in considering students' motivations when developing PBL curriculum. However, a longitudinal understanding of how motivation and perceptions of value in PBSL remains poorly understood.

In this work, we extend Jones et al.'s [27] work by understanding motivation for students entering PBSL courses and contrasting that to the most important learning outcomes achieved from these experiences. These findings contribute to the active dialogue on the role of PBSL in engineering education.

2.3 Project-based Service Learning, Retention and Persistence

Only 40% to 60% of students enrolled in an engineering major persist in obtaining an engineering degree, with the retention of women and minorities in engineering majors is at the lower end of the range [28]. Furthermore, of the students who persist and graduate with an engineering degree, a little less than half enter the science and engineering (35%) or related (14%) workforce [29]. Highlighting engineering as a field that can serve a broader societal impact, in contrast to a technology-centric view [30, 31], and "[introducing] engineering activities, such as team-based design projects and community service projects, early in the undergraduate experience alongside basic science and math courses, so that students begin to develop an understanding of the essence of engineering as early as possible" [28] have been identified as needed changes to engineering education to improve retention in engineering.

3. Methods

3.1 Course Details

We examine three years of course data collected from 70 students enrolled (Table 1) in an interdisciplinary social impact driven, project-based design course over this period. All course offerings attracted students from a variety of disciplines, including Engineering, Environmental Economics and Policy, Law, Business, Public Health, City Planning and Cognitive Science, and a combination of undergraduate and graduate students, although graduate students were the majority. We note that beyond enrollment status, we did not collect other sources of distinction between undergraduate and graduate students (e.g., years of work experience). Data collected and analyzed provide insight into students' motivations for enrolling in the course (N = 70 course applications), the goals students set for themselves during the course (N = 209 goal statements), and students' self-perceived value (N = 68 final reflections) after completing the course. Beckman and Barry's innovation as a learning process inspired the innovation model for the course [23]. Projects sourced for the course focused on complex sociotechnical challenges related to disaster response, recovery and resilience [24] with a significant social impact. The objective to foster the development of students' sociotechnical thinking skills, i.e., the ability to integrate social and technical dimensions in solving a design problem [25], and increase students' sociotechnical fluency, i.e., students' confidence in navigating between both dimensions, inspired the types of problems sourced as course projects.

In Innovation in Disaster Response (Sp20), a project-based course, students leveraged technology toolkits (e.g., machine learning, Internet of Things (IoT), augmented reality/virtual reality (AR/VR)) to work on challenges related to disaster response. Students learned and utilized methods from design and systems thinking to create a technology-based intervention that addresses specific needs identified by problem partners (including Google.org and the World Bank). Interventions were designed for specific use cases, tested, and presented to a committee of external stakeholders for feedback at the end of the course.

In Innovation in Disaster Response, Recovery and Resilience (Sp21, Sp22), a project-based course with projects sourced in partnership with the National Security Innovation Network, students practiced framing and solving actionable, human-centered problems from a complex systems space: Disaster Response. Students designed technology-based interventions that address specific needs identified through the process of the class. Students developed fluency in key concepts in disaster response, while developing expertise in the following toolkits: design thinking, systems thinking, and emerging technologies. Interventions were presented to a committee of stakeholders for feedback at the end of the course. Fig. 1 shows when each course was offered.

Each three-unit course was structured such that work was completed by students both inside and outside of class. University policy establishes that

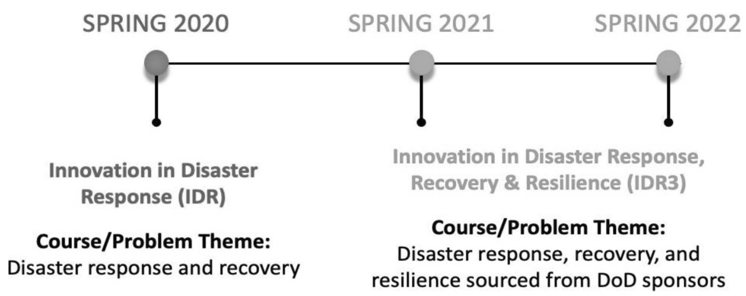

Fig. 1. Course offerings and themes.

Table 1. Course applications and enrollment

Course	Gender				Discipline				Class Standing			
	Male		Female		Engineering		Non-engineering		Undergraduate		Graduate	
	Applied	Enrolled	Applied	Enrolled	Applied	Enrolled	Applied	Enrolled	Applied	Enrolled	Applied	Enrolled
IDR-Sp20	18	10	29	13	19	9	28	14	15	7	32	16
IDR3-Sp21	16	12	21	17	25	21	12	8	9	5	28	24
IDR3-Sp22	16	14	11	8	16	15	11	7	7	4	20	18

classes consume three hours per unit per week. Three hours per week was reserved for classroom work and students were expected to spend at least six hours per week outside class working on developing a deep understanding of the complex social, political, and technical systems we are studying and then on developing and testing solutions to shift those systems.

3.2 Course Participants

All course offerings were open to both undergraduate and graduate students from all departments. Students interested in enrolling in the class were required to fill out an online course application. Each course was cross-listed under multiple departments including Development Engineering, Mechanical Engineering, and Design Innovation.

The course curriculum was graduate-focused. Graduate students made up a majority of students who applied for and enrolled in IDR (Sp20) and IDR3 (Sp21 & Sp22); however, course applications from upper class undergraduate students were evaluated and admitted. Considering that much of the PBSL literature published to date investigates PBSL opportunities for undergraduate students, this research provides a unique exploratory study with a primarily graduate student class as a comparison to the prevalent literature with undergraduate students. Insights from this exploratory study could be used to motivate future research efforts. This study was developed to adapt to an existing course structure and model. As a result, there are numerous variables outside of our control in this study, leading to limitations in the broader generalizability of this work which are discussed in more detail in Section 6.

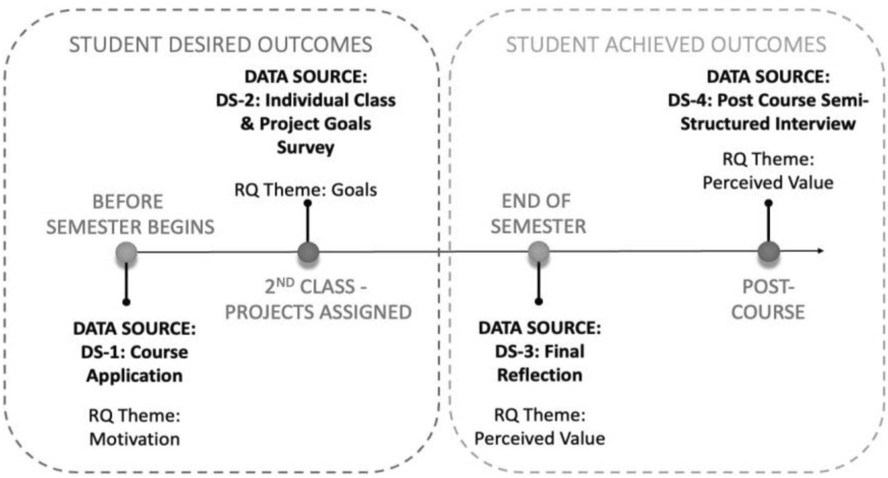

Fig. 2. Data sources and collection sequence.

3.3 Data Sources

The data sources collected to assess students' motivations for taking the course, students' goals, and perceived value of the course are captured at different points in time with respect to students' engagement with the course, ranging from before the course, at the beginning of the course, and at the conclusion of the course. The timeline shown in Fig. 2 shows when each data source was collected relative to the semester. In accordance with an approved human subject's protocol, course enrollment application, surveys, short responses, and a final course reflection were collected and analyzed; each of these data assets prompted students with specific questions to elicit their motivation for and perceived value of the course experience (Table 2). Data sources were individual student assignments and were analyzed at the student level using document analysis (DS-1, DS-2, DS-3) and narrative analysis (DS-4).

3.4 Coding Framework and Analysis

Using a reflexive thematic analysis approach, preliminary coding themes and subcodes were inductively generated and assigned based on initial patterns recognized in students' responses to surveys in the first offering of the class. Additional data sources were coded using the initial codes generated to determine how well codes and themes generated identified and captured the themes from the larger data set and the codebook was updated accordingly. Students' motivations for taking the course, the goals they set for themselves and their projects, and their perceived value were captured through the data sources described in Section 3.3. Student responses were coded for these themes and codes (Table 3).

Qualitative analysis broadly followed a team-based consensus approach for interrater reliability [32]. Two researchers familiar with all three offerings of the Innovation for Disaster Response (Sp20) and Innovation in Disaster Response, Recovery,

Table 2. Overview of data sources and intended use

DS-X: Data Source	Timing	Data Type / Analysis	Sample Size
DS-1 Course Application *"Please write a few sentences establishing your interest and motivation to join our class. What do you find interesting about this topic? How might it connect to your personal goals?"*	Collected before the semester begins	Short response Content/ Document Analysis	*N = 70* (Average of 23 per class-year) Single response, multiple codes possible
DS-2 Individual Class and Project Goals Survey *"What goals do you have for the semester/project?"*	Collected during the 2nd class, after projects assignments announced	Short response Content/ Document Analysis	*N = 209* (Average of 70 per class-year) Multiple responses (3–5) per student, each response coded individually
DS-3 Final Reflection *Describe your personal learning – shifts in mindsets, development of skillsets, knowledge of new tools – from the course* • *How did the course differ from or align with your expectations of the course at the beginning of the semester?* • *What did you learn most about yourself during the course?* • *What did you learn most about or from others?*	Collected at the conclusion of the semester	Long response (500–750 words), reflection prompt	*N = 68* (Average of 23 per class-year) Single response, multiple codes possible
DS-X: Data Source	**Timing**	**Data Type / Analysis**	**Sample size**
• *How did the course shift your perspectives? About life? About work?* • *What did the course help you to learn about your current life objectives and intentions?* • *What do you think you can use from the class going forward?*		Content/ Document Analysis	
DS-4 Post-Course Semi-Structured Interview • *Can you provide a brief summary of your professional career since completing Innovation in Disaster Response/Innovation in Disaster Response, Recovery, Resilience in Spring 2020/2021/2022?* • *In retrospect, did you find the course to be useful during your academic studies? If so, are there any specific lessons you learned, or skill sets you developed from the course that you found helpful/valuable during your academic studies?* • *In retrospect, did you find the course to be useful in your professional practice? If so, are there any specific lessons you learned, or skill sets you developed from the course that you found helpful/valuable in your professional career?* • *How, if at all, did participating in the course help better prepare you to understand or identify potential career paths for yourself?* • *From your experience in industry to date, how would you change the course to help better prepare current students in their careers?*	Collected 1–3 years after the conclusion of the course	Interview (Average 27 minutes) Narrative Analysis	*N = 12* (Average of 4 per class-year)

Table 3. Themes and codes

Theme / Description	**Subcodes**		**Sample Responses**
Theme 1: Develop / apply technical skill sets and content knowledge The development/ acquisition or application of discipline, course, or problem domain specific content knowledge or techniques.	Sub-code 1	**Discipline-specific knowledge & skills** (e.g., application of from previous knowledge from engineering class and apply to things)	"Hone my skills in UX" "I am a Mechanical Engineer who has a passion for software, and I'm looking for an opportunity to apply my current skills (UI design, microcontroller programming, web development) as well as new ones (Machine Learning/AI)."
	Sub-code 2	**Course technology-specific:** Skills based on the course directly (course description, syllabus), excluding design methods / processes	"I wish I could explore AR/VR or other technology applied in specific problems in this course." "For my last round of data analyses for research, Tableau helped create the visualizations that I wanted firsthand before creating custom visualizations in R or Python"
Theme / Description	**Subcodes**		**Sample Responses**
	Sub-code 3	**Problem-specific** knowledge and skills (e.g., content knowledge related to a specific problem space or disaster response more generally)	"I would like to become more familiar with state-of-the-art applications of technology for disaster response." "Learn more about resilient position, navigation and disaster response methods"
Theme 2: Develop / apply professional skill sets The development/ acquisition or application of professional skill sets, such as interpersonal skills, communication, time management, etc.	Sub-code 1	**Teamwork / Interpersonal Skills**	"I also learned how important it was, especially in this space, to work together in a group to take advantage of everyone's different backgrounds and perspectives"
	Sub-code 2	**Communication Skills**	"Learn how to constructively communicate feedback to improve ideas (w/o being rude and sapping energy)."
	Sub-code 3	**Time Management Skills**	"Something I've always struggled with was the work-life balance, always favoring work up to the point where it ruined my health, but through them I was inspired to find ways to take care of myself while still maintaining a high level of work."
	Sub-code 4	**Project Management and Leadership Skills**	"I want to be able to be proud of my project and develop my project management skills."
	Sub-code 5	**Client Engagement / Relationship Skills**	". . . the less tangible experiences of need finding and stakeholder management are skills that will be generally useful for my life and career"
Theme 3: Develop / apply design skills / processes The development/ acquisition or application of design mindsets and processes (approaching a problem).	Sub-code 1	**Research, Interviewing, and Data Collection**	"I find that often it can be difficult for me to reach out to people and simply ask them to talk, but this class requires me to move out of my comfort zone and just blast emails around (. . .). While we had a lot of ignored emails, we also had a ton of people willing to help. Having the confidence to reach out for help is something that I know is a challenge for me and is something I've been trying to improve at for a while – and this class definitely helped me with that."
	Sub-code 2	**Frame and Reframe Problems**	"I think as engineers many times we tend to provide solutions to problems as we understand them and often take little time to understand the problem from the many stakeholders' perspective (. . .).This class focused on learning to question the framing of the problem and often focusing on stakeholders' needs trying to find a solution that is manageable and possible."
	Sub-code 3	**Ideation and Solution Development**	"Ideate both tech-related and non-tech solutions"
	Sub-code 4	**Prototyping and Experimentation**	"The range of prototypes I imagine possible in design classes has undoubtedly been expanded due to IDR3."
	Sub-code 5	**Design Thinking / Human Centered Design**	"I have worked on numerous projects that revolved around customer and user insights and this class project was a prime example of how design should be user-centric and not designer-centric, i.e. not what I want to design but who I should design for. Having that mindset pushed us to realize that we need to identify the needs of the firefighters rather than what we think would be a cool gadget to design that might not be as helpful to them."
	Sub-code 6	**Systems Thinking**	"I really enjoyed the guest lecture that we had about systemic thinking and creating the feedback loops was something that I will remember and use in my future work."

Table 3. Themes and codes (*continued*)

Theme / Description	Subcodes		Sample Responses
Theme 4: Achieve impact-oriented outcome The desire to work on a meaningful project or achieve an impact-oriented outcome.	Sub-code 1	**Product / Project Outcome:** building something tangible	"Create a physical prototype to demonstrate our solution to the project. The prototype does not have to be fully functional, but it would be great to have a tangible outcome from this class."
	Sub-code 2	**Academic Outcome:** help me succeed in school	"As a mechanical engineer pursuing a certificate in design, this course fulfills the Advanced Design criteria"
	Sub-code 3	**Professional Outcome:** help me succeed in career	"Achieve a UX product and put it in my portfolio."
	Sub-code 4	**Change Outcome:** Doing good	"Do something good." "I'm particularly excited about expanding my design process skills while working on a project that matters."
Theme 5: Journey for career clarity Clarity regarding future professional goals and/or paths.	Sub-code 1	Clarity regarding the **type of role**	"Personally, this course also helped confirm for me that I want to follow the managerial path rather than a technical path in my career. Having a working prototype is awesome, but just that by itself isn't enough – you need so many people in so many different focuses to make a project succeed, and I really enjoyed helping to puzzle out where all the different pieces of the project came together to get the information needed to support the physical designs."
	Sub-code 2	Clarity regarding the **type of work/project**	"Consider possible career path in disaster response and building resiliency." "This course really made me think about my next steps and potential career. After finishing this project, I realized that design is not my dream job or passion in life. While I enjoyed this course and all the steps we took to build our final deliverable, the teambuilding and conversations were a much higher point for me."
	Sub-code 3	Clarity regarding the **type of organization or team**	"I've never felt the desire to join with a government entity. While there are certainly parts of the government I disagree with, it was a great experience to be able to speak with those who truly seem to have it in their hearts to serve the people (. . .). While I'm still not inclined to join a government entity, I can now see their importance and I would be less apprehensive about aiding in a government effort if it were something that I could see a direct effect on helping the people. It's given me something to think about as I move on to choose a career."
	Sub-code 4	Clarity regarding **professional values**	"This course helped me learn about my own objectives to become an engineer that can contribute to the world in a way that saves lives and alters futures. I always have hoped to do this with my technical knowledge, but this class showed me that I have the capability to do so, and there are many people who are older and in the industry that take great interest in supporting these endeavors." "The guest speakers who joined us in class empowered me to find a career path (maybe not now, but in the future) that can still align engineering work with my interests to make an impact on saving lives and creating a better world."

and Resilience (Sp21 and Sp22) courses identified subcodes for each theme identified. To identify any modifications or clarifications needed to code definitions, both researchers iteratively coded a subset of the data from the course applications (DS-1), goals survey (DS-2), and final reflections (DS-3) and then compared the codes applied to each response. This iterative process of coding responses, comparing codes applied, and reconciling disagreements with the goal of more robustly establishing consensus was completed three times for at least 25% of the total data set for DS-1, DS-2, and DS-3 from IDR (Sp20), IDR3 (Sp21), and IDR3 (Sp22); both researchers performed the same coding tasks. This iterative process resulted in clarifications to code definitions to clearly articulate responses that would or would not be included for each code. The final codebook with themes, sub-codes, and sample responses is shown in Table 3. A final inter-rater reliability of >90% was achieved after three rounds of coding, and Cohen's Kappa values indicated that both coders were in near perfect agreement for 20 codes, substantial agreement for one code (Theme 1, Subcode 3: Problem-Specific Knowledge and Skills), and moderate agreement for one code (Theme 3, Subcode 5: Design Thinking/Human-Centered Design).

Finally, while multiple codes could be assigned to a

Table 4. Student desired outcomes by theme

Theme Prevalence	Student Achieved Outcomes	
	Motivations (DS-1, N = 70)	**Goals (DS-2, N = 209)**
1. Most Prevalent ↕ 5. Least Prevalent	Theme 4: Achieve impact-oriented Outcome (*n = 79*)	Theme 4: Achieve impact-oriented outcome (*n = 64*)
	Theme 1: Technical skill sets and discipline-specific knowledge (*n = 40*)	Theme 2: Develop/apply professional skill sets (*n = 64*)
	Theme 3: Develop/apply design skills/ processes (*n = 43*)	Theme 1: Technical skill sets and discipline-specific knowledge (*n = 34*)
	Theme 2: Develop/apply professional skill sets (*n = 25*)	Theme 3: Develop/apply design skills/ processes (*n = 50*)
	Theme 5: Journey for career clarity (*n = 10*)	Theme 5: Journey for career clarity (*n = 4*)

single response, a single response was not coded to designate multiple instances of the same code. Responses were coded for existence of a code, not the frequency of a single code in a single response. This means that the nuanced insight of the number of times a specific code was referenced wasn't captured in the coding. Coding for the number of times a single code presents in a response may provide additional insight to the relative value of different codes and could be considered as future research. This nuanced difference in coding could provide more insights for longer student responses such as the final reflection and the post-course interviews.

4. Results

The results presented include data from all students, including both engineering and non-engineering students, as well as both graduate and undergraduate students. Participant demographics are presented in Table 1.

4.1 R1: What Motivates Students to Pursue Design Project-Based Service-Learning Experiences and what Learning Outcomes do they Seek from such Experiences?

Students indicated the desire to achieve an impact-oriented outcome (Theme 4) and the desire to develop/apply technical skill sets and content knowledge (Theme 1) most frequently in the course application (DS-1, Table 4). Overall, 73% of students (79% of male students, 67% of female students; 74% of engineering students, 70% of non-engineering students; 65% of graduate students, and 100% of undergraduate students) indicated at least one motivation related to achieving an impact-oriented outcome (Theme 4) in course applications (DS-1). Similarly, 47% of students (41% of male students, 53% of female students; 47% of engineering students, 48% of non-engineering students; 44% of graduate students, and 56% of undergraduate students) indicated at least one motivation related to developing/applying technical skillsets and content knowledge (Theme 1) in course applications (DS-1).

At a more granular level than the high-level themes, student motivations and goals were described by codes (Table 5). Achieving a Change Outcome emerged as the most prevalent motivation and goal across the DS-1 and DS-2 instruments, with Teamwork, Product/Project Outcome, and Problem-Specific Knowledge as other highly prevalent codes.

More specifically, the impact-oriented outcomes students were most motivated by were the desire to achieve a change outcome, such as working on

Table 5. Student desired outcomes by codes

	Student Desired Outcomes	
	Motivations (DS-1, *N = 70*)	**Goals (DS-2, *N = 209*)**
3 Most Coded Student Responses	Change outcome – Th 4 (*n = 41*)	Change outcome – Th 4 (*n = 33*)
	Product/project outcome – Th 4 (*n = 23*)	Teamwork/interpersonal skills – Th 2 (*n = 30*)
	Problem-specific knowledge & skills – Th 1 (*n = 25*)	Problem-specific knowledge & skills – Th 1 (*n = 25*)
	Motivations (DS-1, *N = 70*)	**Goals (DS-2, *N = 209*)**
3 Least Coded Student Responses	Academic outcome – Th 4 (*n = 2*)	Course technology-specific knowledge and skills – Th 1 (*n = 2*)
	Communication skills – Th 2 Project management/leadership skills – Th 2 Frame and reframe problems – Th 3 Type of organization/team – Th5 Professional values – Th 5 (*n = 1*)	Time management skills – Th 2 (*n = 1*)
	Time management skills – Th 2 Type of role – Th 5 (*n = 0*)	Type of role – Th5 Type of organization/team – Th 5 Professional values – Th 5 (*n = 0*)

large-scale meaningful problems (e.g., climate change) or more general altruistic motives such as "create[ing] something that can save human lives" and "do[ing] something good." Of the students who enrolled in the course, 59% of students cited the desire to achieve a change outcome as motivation for joining the course. The desire to achieve a product/project outcome (e.g., develop a portfolio product), was the second most common impact oriented outcome, which was present in 33% of enrolled students' course applications, DS-1.

Less prevalent were codes related to gaining career clarity (Theme 5). Only 13% of students (24% of male students, 3% of female students; 14% of engineering students, 11% of non-engineering students; 15% of graduate students, and 6% of undergraduate students) indicated at least one motivation related to gaining career clarity (Theme 5) in the course application (DS-1).

4.2 R2. How do Student Anticipated Benefits (i.e., Motivations, Goals, Perceived Value) Evolve over the Course of a PBSL Experience?

Students' motivations and goals are captured early in their interaction with the course (DS-1 and DS-2) and measured later via instruments DS-3 and DS-4 (Fig. 2). During initial periods of the course, Theme 1: Apply/develop technical skill sets and content knowledge and Theme 4: Achieve impact-oriented outcome are more prominent in students' desired outcomes (Fig. 3). Later in the course, the increased prevalence of Theme 3: Apply/develop design skills/ processes and Theme 2: Apply/develop professional skill sets as the two most prevalent themes in students' self-reported perceived value captured at the completion of the course (DS-3) indicates that students identified these as a valuable outcome from the course. Percentages in Fig. 3 indicate the percent of students who responded with at least one code from each theme. The number of responses that did not have at least one code assigned was not recorded during the data analysis.

Theme 5: Journey for career clarity is another theme that showed a large variation in prevalence across students' motivations, goals, perceived value. Career clarity (Theme 5) was the least prevalent theme in students' desired outcomes – motivations and goals (DS-1 and DS-2) – but increased to the third and second most prevalent themes in students' achieved/valued outcomes – perceived value and longitudinal perceived value, respectively. More specifically, 13% of students indicated at least one motivation related to Career Clarity (Theme 5) in their course application (DS-1) and only 6% of students indicated a goal related to Career Clarity in the goals survey (DS-2). In contrast, 63% of students included at least one perceived value related to Career Clarity in their final reflections (DS-3) and 83% of students reported at least one longitudinal perceived value related to Career Clarity during the post-course interview (DS-4).

4.3 R3. What Outcomes do Students Perceive as Most Valuable from PBSL Experiences?

Students most commonly reported developing/ applying design skills/processes (Theme 3) and developing/applying professional skill sets (Theme 2) as self-reported outcomes from the course in self-reflections submitted at the conclusion of the course

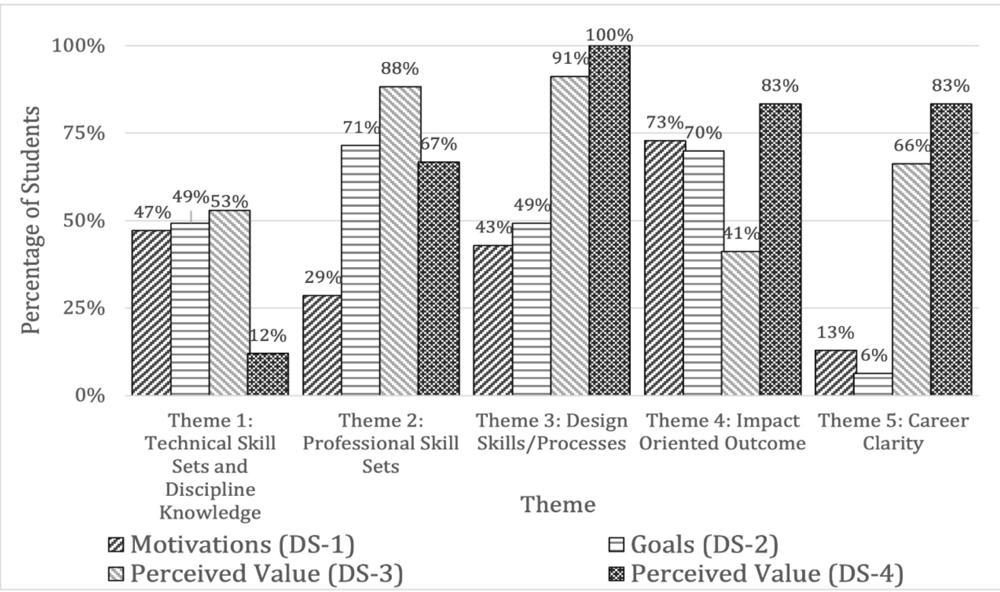

Fig. 3. Prevalence of themes across data source.

Table 6. Student achieved outcomes by theme

Theme Prevalence	Student Achieved Outcome	
	Perceived Value (DS-3, *N = 68*)	**Perceived Value - Longitudinal (DS-4, *N = 12*)**
1. Most Prevalent ↕ 5. Least Prevalent	Theme 3: Develop/apply design skills/ processes (*n = 170*)	Theme 3: Develop/apply design skills/ processes (*n = 35*)
	Theme 2: Develop/apply professional skill sets (*n = 113*)	Theme 5: Journey for career clarity (*n = 17*)
	Theme 5: Journey for career clarity (*n = 70*)	Theme 1: Technical skill sets and discipline-specific knowledge (*n = 12*)
	Theme 1: Technical skill sets and discipline-specific knowledge (*n = 44*)	Theme 2: Develop/apply professional skill sets (*n = 19*)
	Theme 4: Achieve impact-oriented outcome (*n = 40*)	Theme 4: Achieve impact-oriented outcome (*n = 15*)

(Table 6). Overall, 88% of students (90% of male students, 87% of female students; 90% of engineering students, 86% of non-engineering students; 92% of graduate students, and 75% of undergraduate students) indicated developing/applying design skills/processes (Theme 3) as a valuable outcome of the course. Similarly, 85% of students (74% of male students, 95% of female students; 83% of engineering students, 89% of non-engineering students; 88% of graduate students, and 88% of undergraduate students) indicated developing/applying professional skill sets (Theme 2) as a valuable outcome of the course.

Among perceived value illustrated in the personal reflection DS-3 (Table 7), applying/ developing teamwork/interpersonal skills was the most common perceived value coded in students' responses to the final reflection submitted at the completion of the course, expressed by 71% of students (71% of male students, 70% of female students; 68% of engineering students, 75% of non-engineering students; 71% of graduate students, 69% of undergraduate students). Applying/ developing research, interviewing, and data collection skills and processes was the second most common perceived value, expressed by 60% of students (61% of male students, 60% of female students; 65% of engineering students, 54% of non-engineering students; 60% of graduate students, 63% of undergraduate students). Applying/ developing problem framing and reframing skills and processes was the third most common perceived value, expressed by 54% of students (65% of male students, 46% of female students; 55% of engineering students, 54% of non-engineering students; 56% of graduate students, 50% of undergraduate students).

Among perceived value illustrated in the longitudinal interview assessment (Table 7) conducted 1–3 years after the course, gaining career clarity regarding the type of work/project to pursue was the most common longitudinal perceived value coded in students' transcribed responses to the post-course interview (DS-4). From the 12 post-course interviews conducted, 83% of students indicated gaining career clarity regarding the type of work/project as a longitudinal perceived value of the course. Applying/developing research, interviewing, and data collection skills and processes and applying/developing Design Thinking/Human-Centered Design skills were tied as the second most common perceived longitudinal values coded in

Table 7. Student achieved outcomes by codes

	Student Achieved Outcomes	
	Perceived Value (DS-3, *N = 68*)	**Perceived Value – Longitudinal (DS-4, *N = 12*)**
3 Most Coded Student Responses	Teamwork/interpersonal skills – Th 2 (*n = 48*)	Type of work/project – Th 5 (*n = 10*)
	Research, interviewing, and data collection – Th 3 (*n = 41*)	Research, interviewing, and data collection – Th 3 Design Thinking/Human-Centered Design – Th 3 (*n = 9*)
	Frame and Reframe problems – Th 3 (*n = 37*)	Ideation and solution development – Th 3 (*n = 7*)
	Perceived Value (DS-3, *N = 68*)	**Perceived Value – Longitudinal (DS-4, *N = 12*)**
3 Least Coded Student Responses	Time management – Th2 Type of role – Th 5 (*n = 6*)	Course technology-specific knowledge and skills – Th 1 Prototyping and experimenting– Th 3 Systems Thinking– Th 3 Academic outcome– Th 4 (*n = 3*)
	Discipline-specific knowledge and skills – Th 1 (*n = 3*)	Time management skills – Th 2 Product/project outcome– Th 4 Type of role – Th 5 (*n = 2*)
	Academic outcome – Th 4 (*n = 1*)	Project management/leadership skills – Th 2 Professional values – Th 5 (*n = 1*)

students' post-course interviews (DS-4), each expressed by 75% of students.

5. Discussion

5.1 R1: What Motivates Students to Pursue Design Project-Based Service-Learning Experiences and What Learning Outcomes do They Seek from such Experiences?

Most salient among goals and motivations specified in instruments early in the PBSL experience – DS-1 and DS-2 – were related to the theme of "impact-oriented outcome." Codes that were most prevalent within this theme referred to the change outcome – broadly understood, the desire and intention of students to make a positive difference via the PBSL experience. In contrast, motivations and goals expressed the least were broadly under the theme of "career clarity," with especially few students selecting codes such as "type of role," for example.

These results both confirm and extend on existing research. Our findings broadly align with Sevier et al.'s results, that PBSL could enhance students' perception of attention, relevance, and satisfaction over conventional (non-service learning) project [33]. Specifically, we see similar themes, such as students' interest in change outcomes drawing them into service learning, supporting the idea that change outcomes can be correlated to attention and relevance as Sevier et al. describe them [33]. Career clarity, for the students studied, however, did not emerge as a motivation to enroll in the course. While no studies examining the career-oriented motivations of students engaging in PBSL could be found, Painter et al. [34] note that career outcomes were not among the top three motivating reasons that engineering students selected an engineering major. While a different choice than that to enroll in a PBSL course, we expect similar rationale to apply, and our findings align with Painter et al.'s.

To further explore differences in students' motivations based on student populations by gender (male and female), discipline (engineering and non-engineering), and class standing (graduate and undergraduate), a chi-square test of independence was conducted for each of the 22 codes and 5 themes. A chi-square test of independence showed there was a significant relationship between the following two variables:

<u>Gender</u>

- Male students were more likely than female students to indicate gaining clarity on type of work/project as a motivation to join the class, $\chi^2(1, N = 70) = 5.48, p < 0.05$.
- Male students were more likely than female students to indicate gaining career clarity (theme 5) as a motivation to join the class, $\chi^2(1, N = 70) = 6.72, p < 0.05$.

<u>Class Standing</u>

- Undergraduate students were more likely than graduate students to indicate the desire to develop/apply teamwork/interpersonal skills as a motivation to join the class, $\chi^2(1, N = 70) = 6.40, p < 0.05$.
- Undergraduate students were more likely than graduate students to indicate the desire achieve a change outcome as a motivation to join the class, $\chi^2(1, N = 70) = 10.48, p < 0.05$.
- Undergraduate students were more likely than graduate students to indicate the desire develop/apply professional skill sets (theme 2) as a motivation to join the class, $\chi^2(1, N = 70) = 4.67$, $p < 0.05$.
- Undergraduate students were more likely than graduate students to indicate the desire to achieve impact-oriented outcomes (theme 4) as a motivation to join the class, $\chi^2(1, N = 70) = 7.73$, $p < 0.05$.

A chi-square test of independence showed there was no significant association between student populations: gender (male, female), discipline (engineering, non-engineering), and class standing (graduate, undergraduate) and the remaining codes, other than the statistically significant findings described in the above bulleted lists. Considering the smaller sample size for some of the subpopulations compared, a Fisher's exact test was also run on differences that appeared to potentially be significant as a comparison to the chi-square test of independence. The Fisher's exact test results were in alignment with all chi-square test results and did not yield different results.

Some significant associations between graduate and undergraduate students' motivations were exposed in the results of a chi-square test of independence. Mainly, undergraduate students were more likely than graduate students to indicate motivations related to the application/development of professional skill sets (Theme 2) and the desire to achieve impact-oriented outcomes (Theme 4). More specifically, within these themes, undergraduate students were more likely than graduate students to indicate the desire to develop/apply teamwork/interpersonal skills and the desire to achieve a change outcome as motivating factors to enroll in social-impact-driven, project-based design course. A potential hypothesis for undergraduate students' increased motivation for the development of teamwork/interpersonal skills as desired outcomes for the course may be a result fewer "real-world" opportunities to develop these skill sets and as a result they seek these opportunities through courses.

Additionally, significant associations between male and female students' motivations were shown in the results of a chi-square test of independence. Male students were more likely than female students to indicate motivations related to gaining Career Clarity (Theme 5). More specifically, within this theme, male students were more likely than female students to indicate a desire to gain clarity on the type of work/project.

While undergraduate students were the only subpopulation to show a significant increase in motivation to achieve a change outcome, since this code was the most prevalent (reported by 58.6% of all students), highlighting the social-impact aspect of course project may increase student enrollment and engagement, across all subpopulations.

5.2 R2. How do Student Anticipated Benefits (i.e., Motivations, Goals, Perceived Value) Evolve over the Course of a PBSL Experience?

Students were mostly motivated by the opportunity to achieve an impact-oriented outcome (Theme 4) and the development/application of technical skill sets and discipline specific knowledge (Theme 1). However, students more commonly reported the development of design skills/ processes (Theme 3) and the development/application of professional skill sets (Theme 2) as the perceived value of participating in the course. Noting how the prevalence of themes changes considerably between students' motivations, goals, and perceived value, this may indicate a possible misalignment between what students stated as desired outcomes (motivations and goals) and what students reported as achieved/ valued outcomes (perceived value).

Although there is a mismatch between students' desired outcomes and achieved/valued outcomes, this does not seem to correlate to an overall dissatisfaction with the course. To the contrary, students' final reflections (DS-3) were overwhelmingly positive and included comments from students such as "this class was hands down the best one I've taken in my college years" and "this class really helped inspire me to take initiative and begin shifting my career direction towards social good!"

We hypothesize that more tangible outcomes – such as completing the course to satisfy a degree requirement or applying discipline-specific prior knowledge to a real-world problem – are outcomes that students can more easily connect to existing frameworks they have created when determining value or utility, and thus more readily inform their initial motivations for joining the course. However, progressing through the innovation cycle and the project experience– collaborating with team members, navigating multiple project requirements, engaging with project sponsors and other stakeholders, etc.– are learning experiences as well. The complete experience affords a variety of opportunities for the development of less tangible skill sets which may be less evident to students at the beginning of the course and ultimately may culminate in helping inform career clarity of students.

These results contribute to the existing literature on motivation in PBSL and engineering education by tracing the differences between initial motivation and retrospective perceived value. This learning journey accompanying PBSL has been highlighted by Painter et al. and others, with our work contributing further data for the dynamic evolution of student motivations in engineering education.

5.3 R3. What Outcomes do Students Perceive as Most Valuable from PBSL Experiences?

Most commonly reported valued outcomes in students' final reflections (DS-3) were related to the application/development of design skills/processes (Theme 3) and the application/ development of professional skills (Theme 2). This work contributes to prior research indicating positive learning outcomes related to professional skill set development as a result of project-based service-learning, and project-based and experiential learning opportunities more generally. Codes most prevalent in students' perceived value within the theme of professional development cited teamwork/interpersonal skills and communication skills. Regarding the development of teamwork skills, students commonly cited the value of working on diverse teams with diverse backgrounds and skill sets, and the direct impact on the successful outcome of the project.

An interesting concept that emerged from the data was the student's gaining perspective and a better understanding of potential career paths moving forward. Career clarity presented as opportunities to gain a better understanding of the type of role, type of work/project, or type of organization/ team for future professional opportunities. Students' journey for career clarity presented as both "positive" clarity – confirmation of pre-existing ideas or realization of a new possible career path worth pursuing –or "negative" clarity – realization that a potential career path isn't one worth pursuing. Both of which can be valuable clarifying insights for students' regarding their future goals.

Additionally, the development of professional values such as (i) examining beliefs and values and understanding how they influence ethical decision making, (ii) understanding the value of diversity, (iii) understanding ethical issues in engineering practice, and (iv) understanding the importance of lifelong learning [35] were included in students' journey for career clarity.

While students did not participate in the course explicitly seeking opportunities to gain career clarity as a desired outcome (DS-1, DS-2), the significant increase in the prevalence of career clarity in students' achieved/valued outcomes captured at and after the conclusion of the course (DS-3, DS-4), indicates this journey of career clarity is an unexpected, yet valued outcome. These results follow Painter et al.'s findings that community college students engaged in PBSL developed transformative career clarity that they attributed to the PBSL experience, both in terms of individual skills and perceptions of those skills, but also directionality about the choices students seek to make about their future. Our findings build on previous results and suggest that PBSL can offer this career clarity value, but within the STEM and design domains, and to primarily graduate student audiences.

To further explore differences in students' perceived value based on student sub-populations by gender (male and female), discipline (engineering and non-engineering), and class standing (graduate and undergraduate), a chi-square test of independence was conducted for each of the 22 codes and 5 themes. A chi-square test of independence showed there is a significant relationship between the following two variables:

Gender

- Female students were more likely than male students to indicate developing/applying time management skills as a perceived value, $\chi^2(1, N = 68) = 5.14, p < 0.05$.
- Female students were more likely than male students to indicate applying/developing project management and leadership skills as a perceived value, $\chi^2(1, N = 68) = 4.45, p < 0.05$.
- Female students were more likely than male students to indicate applying/developing client engagement/relationship skills as a perceived value, $\chi^2(1, N = 68) = 4.45, p < 0.05$.
- Female students were more likely than male students to indicate the applying/developing professional skill sets (theme 2) as a perceived value, $\chi^2(1, N = 68) = 6.42, p < 0.05$.

A chi-square test of independence showed there was no significant association between student subpopulations: gender (male, female), discipline (engineering, non-engineering), and class standing (graduate, undergraduate) and the remaining codes, other than the statistically significant findings listed above. Considering the smaller sample size for some of the subpopulations compared, a Fisher's exact test was also run on differences that appeared to potentially be significant as a comparison to the chi-square test of independence. The Fisher's exact test results were in alignment with all chi-square test results and did not yield different results.

Some significant associations between male and female students reported perceived value were shown in the results of the chi-square test of independence. Mainly, female students were more likely than male students to indicate the application/development of professional skill sets (Theme 2) as a perceived value of participating in the course. Specifically, within Theme 2, female students were more likely than male students to report the application/development of time management skills, team management/leadership skills, and client engagement/relationship skills as a perceived value of participating in the course. These findings are in alignment with previous studies reporting the development of professional skill sets through PBSL [8–10] and prior work indicating that female students report service-learning opportunities as the source of their technical and professional skills significantly higher than male students [9]. Additionally, Wang et al. [36] reported that leadership modules embedded in service-learning increased female students' confidence in their leadership, more when compared to male students.

While female students were the only subpopulation to significantly be more likely to report perceived value related to developing/applying professional skill sets (Theme 2), this theme was increasingly reported as a valuable outcome from all students as they progressed through the course experience. Before the start of the course, only 28.6% of students indicated the application/development of professional skill sets as a motivation for enrolling in the course. However, at the completion of the course, 85.3% of all students indicated the application/development of professional skill sets as a perceived value of participating in the course. Considering that the difficulties of managing teamwork among students has been cited as potential barriers and difficulties in the implementation of PBL and PBSL opportunities [12, 13, 27], further exploration into the strategies employed in these course offerings that may have contributed to students' positive experiences regarding teamwork could be valuable for other PBL instructors.

6. Conclusion & Future Work

6.1 Implications for Engineering Design Education Practice and Research

These results offer several interesting implications for engineering design education practice and research. In terms of practice, these findings offer preliminary evidence that students who are drawn to PBSL experiences for change outcomes actually retain career clarity and career goals as the most sustained outcomes from the course. This has many implications for how PBSL courses are positioned in engineering curricula and more broadly integrated into engineering education to promote retention and transition of engineers into practice in the field. Following further research to further explore and validate these findings, PBSL experiences could be integrated into undergraduate and graduate curricula different. For undergraduate students, PBSL experiences could be moved earlier in the curriculum to ensure retention of students and attract more students to change outcomes. For graduate students, PBSL experiences could be leveraged for professional development and career clarity establishment from the earliest stages of the program. Similarly, as a potentially powerful asset to support ongoing STEM retention efforts, PBSL can offer a pathway for students to pursue career clarity, especially for students who might be disinclined to seek explicit career counseling on their own.

For research, these findings advance the state of knowledge on motivation in PBSL and present opportunities for further investigation. In particular, a deeper understanding of *why* career clarity emerges from PBSL experiences is necessary. Such an understanding would help further develop PBSL as an explicit career-development opportunity alongside its core engineering learning objectives. Similarly, a careful understanding of what specific PBSL experiences and curricular features explain the gap between motivations to join the class and perceived value of learning outcomes is necessary. This knowledge would help researchers validate PBSL curricula and help scale up PBSL models across universities worldwide.

6.2 Limitations & Future Work

Like any longitudinal study of an uncontrolled environment, there are numerous variables outside of our control in this study, leading to limitations in the broader generalizability of this work. Beyond this, our work has several more specific limitations, which we address here as *small sample size, participant selection and definition* limitations, and limited *codebook validity*. First, regarding *small sample size:* although this study examines several years' worth of data and numerous instrument responses, this data is in the context of only one course offering at one university. Given that we analyze course outcomes and regular curricular assignments, there is no control group to benchmark the motivation dynamics observed here. Second, regarding *participant selection and definition*: we did not collect information on participants' past service experience or broader service orientation; this is a factor that could shape the outcomes that students both sought and perceived. Additionally, participants chose to apply to the class and instructors selected student applicants to meet class size limits, resulting in two layers of participant selection. Furthermore, given the relatively long period between the course experience and interviews (approximately three years), participant selection for interviews was limited by the students who could be contacted despite their non-affiliation with the university. Thus, this sample cannot be viewed as random nor broadly representative of undergraduate and graduate students generally. Last, regarding *codebook validity*, we acknowledge that while consensus-based methodologies for interrater reliability in qualitative coding are widely accepted [32], using such methods with three or four coders – as opposed to two as in this work – may yield more robust and generalizable results.

Despite these limitations, this research has several interesting implications for design educators and researchers. For design educators, our findings suggest that many students have a mismatch of value expectations from the course – that they are drawn to PBSL for solving problems but leave appreciating the *process* of design problem solving. Similarly, the career clarity provided by PBSL experiences appear transformative for several students, suggesting that design educators could build visibility for their PBSL programs and courses by emphasizing that aspect. For design researchers, our work contributes a longitudinal study of motivation across a design-driven PBSL course, offering new knowledge about the role and evolution of motivation in driving student participation in STEM learning experiences.

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Deniz Dogruer is COO and co-founder of Squishy Robotics where she leads strategic partnership efforts, customer development efforts, and supports business operations and strategic planning. She has extensive experience in Design Thinking, Lean Launchpad Methodology, and has co-instructed Hacking4Defense courses at UC Berkeley. She holds a BS and MS in Mechanical Engineering from the University of Nevada Reno, and a PhD from UC Berkeley, focusing on Studies in Engineering, Science and Mathematics Education. Prior to starting her PhD, she taught middle school math and science for 5 years and developed hands on, interactive science cand engineering lesson plans for a local non-profit, Science is Elementary.

Vivek Rao is faculty member at the Institute for Enterprise Engineering at Duke University's Pratt School of Engineering, where he is developing and launching the new Masters of Engineering in Design and Technology Innovation. Prior to joining Duke, Vivek held multiple roles at the University of California, Berkeley (UC-Berkeley), as a professional faculty member in the Haas School of Business; as a postdoctoral researcher in Mechanical Engineering in the field of engineering design theory and methodology, and as an inaugural faculty member of the Berkeley Masters of Design program in the College of Engineering, where he developed and taught foundational courses of the degree.

Before returning to academia, he worked as a designer and strategist at IDEO, where he helped Fortune 500 clients innovate in sectors ranging from pharmaceuticals to furniture, and as a process R&D engineer at the San Francisco Public Utilities Commission Wastewater Enterprise. He holds a BS, MS, and PhD, all in Mechanical Engineering, from the University of California, Berkeley.

Alice Merner Agogino is the Roscoe and Elizabeth Hughes Professor of Mechanical Engineering Emeritus and Professor of the Graduate School at the University of California at Berkeley. She served as Founding Chair of the Graduate Group in Development Engineering, Education Director at the Blum Center for Developing Economies, Chair of the UC Berkeley Academic Senate and Associate Dean of Engineering. She also served on the Executive Committee for the SESAME (Studies in Engineering, Science and Mathematics Education) PhD program at UC Berkeley. She has supervised 197 MS projects/theses, 66 doctoral dissertations and numerous undergraduate researchers. Agogino has authored over 300 peer-reviewed publications and has won numerous teaching, mentoring, best paper and research awards. She is a member of the National Academy of Engineering (NAE) and has served on a number of committees of the National Academies. She received a PhD from Stanford University in Engineering Management & Systems, MS from UC Berkeley and BS from University of New Mexico in Mechanical Engineering.