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Social-Impact Driven Experiential Learning: Student Motivations, Goals and Perceived Value

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Social-Impact Driven Experiential Learning:
Student Motivations, Goals and Perceived Value

By

Deniz Evrensel Dogruer

A dissertation submitted in partial satisfaction of the

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University of California, Berkeley

Committee in charge:

Professor Alice M. Agogino, Chair
Professor Sara L. Beckman
Professor Kosa Goucher-Lambert

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Abstract

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Professor Alice M. Agogino, Chair

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. Surveys of new engineering graduate employers and recent engineering alumni both confirm these professional skills as the most important skills required for current engineering jobs. However, employers report a capability gap exists between expected competencies and the competencies of recent engineering graduates. Studies have shown that experiential learning opportunities, such as Project-Based Learning (PBL) and Project-Based Service-Learning (PBSL), promote the development of such professional skills. While PBSL opportunities integrated into undergraduate curriculum has been more widely investigated, the integration of PBSL opportunities in graduate education hasn't been as extensively explored.

Engineering design pedagogy has increasingly integrated PBSL across the curriculum for its promise of greater engagement of students, transfer of desirable skills, and improved student retention and persistence in STEM. This research evaluates three years of a project-based engineering design course integrating a core PBSL element (social-impact driven projects), 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 one to three years after the PBSL experience, this research investigates how student motivation for engaging in PBSL aligns with the actual perceived value that students derive from PBSL experiences. With a diverse student population (46% male, 54% female; 59% engineering, 41% non-engineering), and large graduate student population (76% graduate, 24% undergraduate), this study provided a unique comparison to the existing PBSL literature, which has predominately focused on undergraduate students to date.

Comparing students' desired outcomes—motivations (n=70 course applications) and goals (n=209 goal statements)—to their self-reported achieved/valued outcomes—perceived value (n=68 reflections) and longitudinal perceived value (n=12 interviews—this research suggests that many students have a mismatch of value expectations from the course. More specifically, students are drawn to the social impact driven, project-based design course by the desire to solve problems but leave appreciating the *process* of design and problem solving. Approximately 88% of students reported the application/development of design skills/processes as a valued outcome of the course. The most cited design skills/processes were research, interviewing and data collection skills and problem framing and reframing, 60% and 54%, respectively. In post-course interviews, 100% of the 12 students interviewed referenced design skills/processes as a valuable outcome of the course.

Additionally, students valued gaining career clarity—confirmation of pre-existing career paths, identification of new career paths, or a realization that a potential career path isn't of interest to pursue—all of which are valuable insights for students' regarding their future goals. While most students did not indicate gaining career clarity as a motivation to enroll in the course (only 13% cited career clarity), 63% of students indicated gaining career clarity—clarity on the type of role, type of work/project, or type of organization/team—regarding their future professional goals as valuable outcome of the course at the conclusion of the semester. Specifically, 53% of students indicated gaining clarity on the type of work/project they would like to pursue, with most indicating a desire to work on social-impact driven projects in their future work.

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 design process understanding and career clarity. 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.

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Acknowledgments

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Chapter 1 Introduction and Research Motivation

1.1 Current Gaps in Engineering Education

Recognizing that the role and scope of the engineering profession is rapidly transforming and "driven by concern that engineering students of today may not be appropriately educated to meet the demands that will be placed on the engineer of 2020" (National Academy of Engineering [NAE], 2005, p. xi), the Committee of Engineering Education of the National Academy of Engineering created The Engineer of 2020 Project. This project resulted in two key reports: i) outlining the vision for engineering and the work of the engineer in 2020 and ii) compiling a critical analysis of the current engineering education curricula, providing recommendations to transform engineering education to better prepare the future engineer. Similar critical analyses that assess current education standards in the United States to meet ever-changing workforce demands are ongoing. For example, In July 2008, the American Society of Mechanical Engineers (ASME) Center for Education formed an engineering education task force entitled ASME Vision 2030 with the primary objectives to define the knowledge and skills needed for mechanical engineering graduates to be globally competitive and to provide recommendations for mechanical engineering education curricula (Kirkpatrick et al., 2011).

While undergraduate enrollment in science and engineering has increased in recent years, only 40% to 60% of students enrolled in an engineering major persist in obtaining an engineering degree. The retention of women and minorities in engineering majors is at the lower end of the range (National Academy of Engineering [NAE], 2005). 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 (National Science Board [NSB], 2014). Self-efficacy is related to engineering students' intentions to persist in their major (Lent et al., 2015); however, based on expectancy-value theory, unless students perceive the usefulness and importance of engineering, they will be unlikely to persist in the profession (Mamaril et al., 2016). Additionally, motivational constructs, such as goals, values, self-efficacy, and beliefs, are also important variables in improving student learning outcomes (Pintrich et al., 1993). Highlighting engineering as a field that can serve a broader societal impact, in contrast to a technology-centric view (National Research Council [NRC], 2009; Sochacka et al., 2014), 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" (National Academy of Engineering [NAE], 2005, p. 40) have been identified as needed changes to engineering education to improve retention in engineering.

1.2 Trends in Engineering Education Reform

Recent reports published by the National Academy of Engineering outline the vision for the Engineer of 2020 and educating the Engineer of 2020, concluded that the engineering work environment requires more than just technical engineering knowledge and skills and argues that engineers also require practical ingenuity, creativity, communication skills, high ethical standards, a strong sense of professionalism, leadership, business, and management skills. The increasing complexity and scale of contemporary problems will require engineers to have a systems perspective and work collaboratively on multi-disciplinary teams of experts (National Academy of Engineering [NAE], 2004a).

Engineering education advocates have different perceptions of 'engineering' and 'engineering competence.' Chiefly, two different approaches to engineering education reform have emerged—a market-driven approach and a science-driven approach; such ideological conflicts have only added to the difficulty of making sustainable changes within engineering departments (Jamison et al., 2014). Reformers favoring market-driven approaches to engineering education advocate for the addition of business economics, marketing, management, and entrepreneurship courses, along with on-the-job training with companies. These reformers stress that engineers should engage with networks and systems of innovations in the workplace. In contrast, reformers backing science-driven approaches to engineering education advocate for established engineering fields to be reconfigured into subdisciplines (e.g., product design, nanotechnology), stating that engineers should serve as the professional experts in the workplace. Jamison et al. argue for the need of an integrative, hybrid approach that mixes both the entrepreneurial focus of the market-driven models and the scientific focus of science-driven models, ultimately combining the scientific, technical, social, and environmental dimensions into one comprehensive form of education.

1.3 Competency Gaps in Recent Graduates and Alumni Perceptions of Most Valuable Skills in Professional Practice

Employers report a capability gap exists between expected competencies and the competencies of recent engineering graduates (Dym et al., 2005b; Eskandari et al., 2007; Lattuca et al., 2014), indicating a need for engineering education reform. While the need for engineering education reform due to rapid changes in the engineering work environment (National Academy of Engineering [NAE], 2004a) is widely accepted, how to achieve this reform is not (Borrego et al., 2010).

Employers rate effective communication, use of engineering tools, teamwork, and professional ethics – along with fundamental and engineering problem-solving skills – as the most important engineering skills they look for in job applicants (Lattuca et al., 2006). Furthermore, a survey of managers listed the top three weaknesses of recent B.S.

Mechanical Engineering hires as: a lack of practical experience, oral and written communication, and problem solving/critical thinking (Kirkpatrick et al., 2011).

Similarly, recent undergraduate alumni identified professional skills, such as teamwork, communication, data analysis, and problem-solving as most important in their professional practice (Lattuca et al., 2014; Passow, 2012); graduate engineering alumni rated multidisciplinary teamwork as most useful in their careers (Cobb et al., 2016).

Active-learning and student-centered pedagogies anchored in coursework rich with authentic, real-world problems (Prince, 2004) and educating engineers in the humanities, entrepreneurship, and interdisciplinary subjects (National Academy of Engineering [NAE], 2004b) have been widely recommended to bridge gaps between employer-expected competencies and competencies of recent engineering graduates. Service learning, a subset of active learning, has been shown to have positive outcomes on recruitment in engineering, subject matter comprehension, and student self-reports of motivation, teamwork, and communication (J. Duffy et al., 2009).

1.4 Project-Based Service Learning, Retention and Persistence

Studies have shown that Project-Based Service Learning (PBSL) opportunities promote students' technical skillset development and professional skillset development (Carberry et al., 2013; Duffy et al., 2008; Huff et al., 2016), while also increasing recruitment, retention, and diversity (Bielefeldt et al., 2009; Carberry et al., 2013). Given the promising research indicating that PBSL offers unique learning opportunities to develop key capabilities and the skill sets required for future engineers, the work to explore and study students' motivations to enroll, the goals students set for themselves, and the value students obtain from participating in such learning opportunities can provide valuable insights that can directly inform curriculum development. Such insights can inform the design and implementation of PBSL opportunities. These insights can also help instructors and instructional institutions to better articulate the value students can expect to obtain. Finally, while the study of PBSL opportunities integrated into undergraduate curriculum has been more widely reported and investigated in the literature, the integration of PBSL opportunities in graduate education hasn't been as extensively explored.

1.5 Research Motivation

Given the existing PBSL literature highlighting the positive learning outcomes associated with the key capabilities and skill sets identified as required for future engineers and PBSL, as well as increased recruitment, retention and persistence—exploring students' motivations to enroll, the goals they set for themselves, and the value they obtain from participating in such learning opportunities can provide valuable insight to instructors to inform the design and implementation of such learning opportunities.

This research seeks to explore self-reported learning outcomes of students participating in a social-impact driven, project-based design course. Given the majority graduate student population and the interdisciplinary make-up of students participating in the course (engineering and non-engineering disciplines), this research provides a unique comparison to the existing body of PBSL research, which is highly concentrated on undergraduate student groups.

1.6 Dissertation Outline

This dissertation consists of five chapters. Chapters 1 addresses research motivation. Chapter 2 summarizes relevant theoretical frameworks and prior research underpinning this dissertation research. More specifically, Chapter 2 provides an overview of prior research in project-based learning and design pedagogy, the challenges and barriers to implementation of project-based learning, as well as the role of motivation in student learning outcomes.

Chapter 3 describes the methods of this dissertation research, mainly the i) research questions this research seeks to answer, ii) an overview of an innovative project-based, service-learning design course investigated as part of this research, iii) the participants included in this study, iv) the data sources and measures used, v) the methodology deployed in the identification of the emerging themes from data collected resulting and vi) the development of the codes based on emerging themes identified.

Chapters 4 provides both the results and discussion of results together, grouped by research question. Chapter 4 begins with the descriptive statistics of students who applied for and enrolled in each offering of the course. Subsequent sections of Chapter 4 are devoted to the five research questions this study aims to explore. Results, immediately followed by the discussion of the results, from students' motivations for enrolling the social-impact driven, project-based design course, the goals they set for the semester and their project, the perceived value identified at the end of the course, and their perceived value of the course after working in industry one to three years after completing the course are presented in Chapter 4. Given the diverse student population of enrolled students, a comparison of different student groups—gender, discipline (engineering, non-engineering), and class standing (graduate, undergraduate)—are also included in Chapter 4.

Finally, Chapter 5 provides a summary of conclusions and implications from this research. Chapter 5 concludes with recommendations and suggested future research.

A high-level description of each chapter is as follows:

- Chapter 1: Research Motivation
- Chapter 2: Theoretical Frameworks and Prior Research
- Chapter 3: Methods
- Chapter 4: Results and Discussion
    - 4.1: Descriptive Statistics – Course Applicants and Enrolled Students
    - 4.2: Research Question 1 – Results and Discussion
    - 4.3: Research Question 2 – Results and Discussion
    - 4.4: Research Question 3 – Results and Discussion
    - 4.5: Research Question 4 – Results and Discussion
    - 4.6: Research Question 5 – Results and Discussion
    - 4.7: Limitations
- Chapter 5: Conclusions and Future Research
    - 5.1: Conclusions
    - 5.2: Recommendations and Future Research

Chapter 2 Theoretical Frameworks and Prior Research

2.1 Project-Based Learning & Design Pedagogy

Active learning pedagogies are rooted in constructivist learning theories, recognizing that students build new knowledge on preexisting knowledge (Bransford et al., 2000) and social constructivism. As such, they recognize the construction process takes place primarily within a social construct, putting "special emphasis on the role of the interaction of the learner with her/his social environment" (Bächtold, 2013, p. 2486).

Active learning opportunities have been increasingly incorporated into engineering education curriculum through interdisciplinary capstone courses, first-year design projects, and curriculum-based service-learning projects. (Borrego et al., 2010) studied the diffusion and adoption of such engineering education innovations within institutions by surveying engineering department chairs at institutions across the United States. Responses from 197 department chairs concluded that while 82% of Engineering department chairs surveyed were aware of innovations in engineering education, only 47% reported adoption of student active pedagogies within their department. Reported barriers to adoption include lack of financial resources as well as faculty time and attitudes. Interdisciplinary capstone classes and first-year design projects were among the innovations with the highest adoption rate; Mechanical Engineering and Chemical Engineering departments were found to be the most likely to have adopted active learning pedagogical practices. Of particular interest to this research, when asked about their awareness of service learning, 79% of department chairs reported awareness of service learning as a pedagogical innovation; however, only 23% of departments currently offered it (Borrego et al., 2010).

Design pedagogy is considered critical training, as ''graduates of today are increasingly expected to work in dynamic and fluid ways, able to approach any wicked problem creatively'' (Dixon & Murphy, 2016). Design offers powerful strategies for unlocking creativity and creating solutions for real-world, complex sociotechnical problems (Buchanan, 1992). Courses dedicated to design and innovation typically involve project-based learning (Dym et al., 2005). Previous research has illustrated that while project-based learning outcomes in design education can be achievable by a range of project types (Lande and Leifer, 2009), students, especially student groups historically under-represented in Science, Technology, Engineering and Mathematics (STEM) education, are drawn to projects or service-based projects exploring humanitarian and social challenges (J. J. Duffy et al., 2011; Oehlberg et al., 2010).

In 2007, Beckman and Barry proposed a framework for the innovation process that situates innovation as a learning process (Beckman & Barry, 2007; J. Duffy et al., 2009), building on earlier work in experiential learning theory (Kolb, 1984) and on approaches to design (Owen, 1993).

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” (Bielefeldt et al., 2009, p. 2). PBSL opportunities have been increasingly integrated within engineering education, both as curricular and extracurricular activities. 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 (Coyle et al., 2005). The Service Learning Integrated throughout a College of Engineering (SLICE) program directly integrates project-based, service-learning projects into required courses within the existing curriculum (J. Duffy et al., 2008), with the goal that students take at least one service-learning course each semester. 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., 2009) 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 as significantly higher when compared to male students (Carberry et al., 2013).

While PBSL opportunities integrated into undergraduate curriculum has been more widely reported and investigated in the literature, the integration of PBSL opportunities in graduate education hasn’t been as extensively explored. One example of combining graduate education with PBSL is the case study documented by Talbert, Farnkhopf, Jones, & Houghtalen, (2003), describing the implementation of a structured PBSL course that replaced the thesis requirement for the Master of Science in Environmental Engineering program at the Rose-Hulman Institute of Technology. Graduate students who participated 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.

2.3 Challenges of Implementing Project-Based Service-Learning Opportunities

A survey of engineering department chairs conducted by (Borrego et al., 2010) reported that while 79% of department chairs have heard of service learning as a pedagogical innovation, only 23% of departments currently offered it. The adoption and implementation of PBSL opportunities, and Project Based Learning (PBL) opportunities more broadly, does not come without challenges and barriers. Most notably, PBL is hindered by high time investment on students' and faculty's parts in project management and knowledge application rather than knowledge acquisition (Noordin et al., 2011).

A comprehensive 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 (Chen et al., 2021b). Most relevant to this research are the challenges faced on the individual level, both by faculty and students. Such challenges faced by faculty included difficulty in facilitating student teamwork (Bani-Hani et al., 2018). Similarly, challenges faced by students include a lack of teamwork skills (Bani-Hani et al., 2018; Chaparro-Peláez et al., 2013) and a lack of learning motivation (De Camargo Ribeiro & Mizukami, 2005; Gratchev & Jeng, 2018).

Utilizing a sequential, mixed methods approach, Jones, Epler, Mokri, Bryant, & Paretti, (2013), identified several instructional elements as motivating opportunities that affect a students' engagement in PBL engineering courses. 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.

PBSL presents additional challenges and barriers to adoption as well. Recent work has suggested that the management of partnerships with service organizations can be difficult to sustain and scale to larger classes, that it is unclear how PBSL generally delivers value to partner organization, and that often service-learning courses prioritize student learning over community impact (Brubaker et al., 2022; Choudhary & Jesiek, 2016; Windschitl et al., 2007). Strategies to address these challenges include the scale-up of sociotechnical PBSL across a major university (Pucha et al., 2018) through the use of case studies.

This work extends Jones et al.'s 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.

2.4 The Role of Motivation

The role of motivation in learning and cognition has been widely studied (Eccles & Wigfield, 2002; Pekrun et al., 2002; Pintrich et al., 1993). Student motivation can serve as a driver for choice, persistence, and performance in engineering (Kirn & Benson, 2018; Mamaril et al., 2016). Two common time scales: motivation toward short-term tasks and motivation toward 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 (Kirn & Benson, 2018).

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 (Mamaril et al., 2016) to qualitative methods utilizing interviews and student reflections (Kirn & Benson, 2018; Norback et al., 2014). Sequential mixed methods approaches have also been utilized. Examples of sequential mixed methods include utilizing quantitative surveys to inform and motivate further exploration through qualitative follow-up interviews (Cobb et al., 2016; Huff et al., 2016); as well as the use of qualitative interviews to inform the development of quantitative surveys (Litchfield et al., 2016).

This research utilizes a mixed-methods qualitative approach to understand student motivation at various touchpoints in the PBSL experience via surveys and interviews. Utilizing similar methods to Mamaril et al. and Norback et al., this research extends 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.

Chapter 3 Methods

3.1 Research Questions

Given the promising research indicating PBSL offers unique learning opportunities to develop key capabilities and skillsets required for future engineers, better understanding students' motivations to enroll, the goals they set for themselves, and the value they obtain from participating in such learning opportunities can provide valuable insight to instructors to inform the design and implementation of such learning opportunities. Furthermore, while PBSL opportunities integrated into undergraduate curriculum has been more widely reported and investigated in the literature, the integration of PBSL opportunities in graduate education hasn't been as extensively explored. As a result, the following research questions have been identified.

RQ1: What motivates students to enroll in social-impact-driven, project-based elective courses?
RQ2: What goals do students set for themselves when working on social-impact-driven, collaborative projects?
RQ3: What do students value from social-impact-driven, project-based learning opportunities?
RQ4: How do social-impact-driven, project-based opportunities influence students' perspectives on their future goals?
RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?

3.2 Social-Impact Driven, Project-Based Design Course

Starting in Spring 2019, a new interdisciplinary, project-based design course focused on complex sociotechnical challenges facing communities was developed and offered as an elective course (Rao et al., 2022). Beckman and Barry's innovation as a learning process inspired the innovation model for the course (Beckman & Barry, 2007). The objective was to foster the development of students' sociotechnical thinking skills, i.e., the ability to integrate social and technical dimensions in solving a design problem (Mazzurco & Daniel, 2020), and to increase students' sociotechnical fluency, i.e., students' confidence in navigating between both dimensions. This objective inspired the types of problems that would be the focus of the course.

The historical timeline of the course offerings and key differences between each iteration are illustrated below.

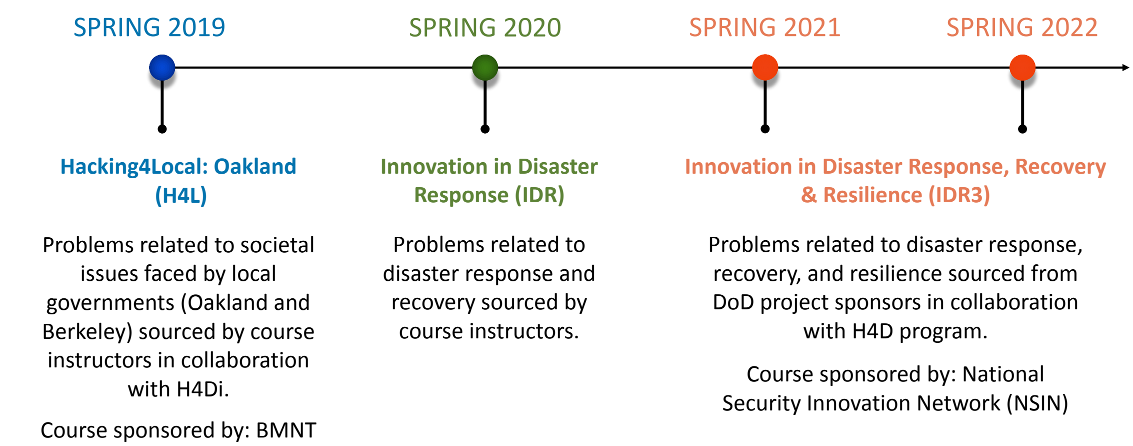


Figure 1: Timeline of Course Offerings

All four course offerings were open to both undergraduate and graduate students from all departments. Details about the students who applied and enrolled in the course are provided in Section 3.3. Additional details about each course offering that was available to prospective students at the time they were evaluating a decision to enroll (or stay enrolled after the first class meeting) are provided in Sections 3.2.1-3.2.3 and notable differences between each course offering are provided in Section 3.2.4.

3.2.1 Hacking4Local: Oakland (H4L) – Spring 2019

Hacking4Local: Oakland (Sp19) is a project-based course that provided students the opportunity to understand and address problems that face governmental organizations, including the Cities of Oakland, Berkeley, and San Leandro. The course informational website[1] described the learning opportunity as follows:

> In the **Hacking4Local** course, student teams develop solutions to help solve important problems faced by the Oakland community. Student teams learn how to apply the **Lean Launchpad and Lean Startup** principles ("mission model canvas," "beneficiary discovery," and "agile engineering") to solve societal problems. Teams discover and validate sponsor needs and continually build iterative prototypes to test whether the problem and solution are understood. Teams take a hands-on approach requiring close engagement with nonprofits, researchers, and end-users (emphasis in original).

Furthermore, the H4L (Sp19) course syllabus outlined the course description, desired outcomes and expectations as follows:

Course Description: Cities face complex challenges and are pursuing creative approaches to solve them - many times with lower resources than optimal. Oakland, in particular,

[1] https://hackingforlocal-oakland.weebly.com/

serves as a model for civic innovation - a large city with a diverse population of people, business, and organizations, embodying complex urban issues ranging from housing, transportation, pollution, to societal issues of policing and human trafficking. Oakland also models success with a track-record of innovative programs and initiatives in policy, social, and environmental arenas.

Hacking4Local is designed to provide students the opportunity to learn how to design solutions to problems that face complex municipal organizations, including the City of Oakland, to better address the challenges faced at the local level including homelessness, hunger, infrastructure, and education. Large institutions come with varied constraints and cities are no different. Using Lean Startup Theory and Human-Centered Design, this course will provide a platform that can develop solution prototypes that match Oakland users' needs in weeks, not months or years. Government offices, related organizations (such as nonprofits or mission-oriented businesses), or investors, may provide follow-on funding to student teams for further refinement and development of solution prototypes.

Over the course of the semester, students in groups of 4 to 5 will tackle a different problem with the help of mentors, advisors, and problem sponsors. The class follows the Lean Startup methodology extended to working in the social sector. The class is taught in a flipped classroom style, where each week the student teams present their progress to the class and receive direct feedback from experts in the field. At the end of the class students will present their journey in a final presentation and hopefully will have designed and validated a solution to the problem they selected.

Potential problem spaces were sourced from local government agencies and organizations by the course instructors. On the first day of class, students were provided with a brief introduction to 15 potential problem statements, shown below. As a homework assignment, students submitted their top three problem choices, as well as indicated a problem they would NOT be interested in working on, if any. Based on survey responses, the five problem statements shown in blue were assigned to five student teams for the semester.

Table 1: Course Projects Hacking4Local: Oakland (H4L) – SP19

Problem Spaces Offered (Problem spaces with student team formed indicated in blue)		
Oakland City Council: Interdepartmental Communications and Constituent Engagement	Hayward City Council: Rent Control Ordinances in Hayward	San Francisco Police Department: Evaluating Community Policing Policies
Oakland City Council: Reserving the Fields	North Beach Citizens: Sustainable Funding	Berkeley City Council: Improving Health in South Berkeley

Alameda County Office of Education: Missing Docs, Missing Life	North Hills Community Association: Can't Stop the Fire	Berkeley City Council: Multi-Modal Transport in Berkeley
Strategic Urban Development Alliance: Standardizing Equitable Development	City of San Leandro: Pop-up Container Food Park	Oakland Airport: Reducing Travelers' Stress
Cristo Rey De La Salle High School: Building a Brand for a New, Alternative Catholic HS	WeAccel: Lower-cost Housing in the Bay Area	Oakland Airport: Noise Abatement at Oakland Airport

3.2.2 Innovation in Disaster Response (IDR) – Spring 2020

Innovation in Disaster Response (Sp20) is a project-based course that provided students an opportunity to work on challenges related to disaster response. The course flyer described the learning opportunity as follows:

> In this class, students will leverage 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 will learn 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 will be designed for specific use cases, tested, and presented to a committee of external stakeholders for feedback at the end of the course. All disciplinary backgrounds welcome - no technical experience is required!

Furthermore, the IDR (Sp20) course syllabus outlined the course description, desired outcomes and expectations as follows:

Course Description: In this class, you will practice framing and solving actionable, human centered problems from a complex systems space: Disaster Response, Recovery & Resilience. Selecting from a range of pre-defined problem sets in the disaster response space sourced in collaboration with the National Security Innovation Network (NSIN), students spend the class immersed in a semester-long project to design a technology-based intervention that addresses specific needs identified through the process of the class. Students will develop fluency in key concepts in disaster response, while developing expertise in key design and technology toolkits: design thinking, systems thinking, and readily accessible platforms to prototype solutions (this semester, we will be exploring augmented reality, data visualization, and cloud-based machine learning services).

Desired Course Outcomes: By the end of the term, students will have proposed a human-centered and technical concept to address their group's challenge area in disaster response, recovery, and resilience, supported by a process narrative, prototype, and video snapshot. Interventions will be contextualized and assessed for their relevance as a follow-on program, initiative, or venture by NSIN, and presented to a committee of stakeholders for feedback.

Expectations: This is a three-unit course. We have structured the work to be done inside and outside the class accordingly. University policy establishes that classes consume three hours per unit per week of your time; in our case you will have three hours per week in the classroom and can expect 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.

Potential problem spaces were sourced by the course instructors. On the first day of class, students were provided a brief introduction to 13 potential problem statements, shown below. As a homework assignment, students submitted their top three problem choices, as well as indicated one problem they would NOT be interested in working on. Based on survey responses, the six problem statements shown in blue were assigned to six student teams for the semester.

Table 2: Course Projects Innovation in Disaster Response (IDR) – SP20

Problem Spaces Offered (Problem spaces with student team formed indicated in blue)			
Translating Forecasts to Actions for Elderly Community Members	Tracking Evacuation Enforcement & Optimization	Long-term Waste Assessment + Removal + Containment	Access to Critical Household Resources
Insurance Payouts for Construction & Repair	Sustainable Rebuilding	Disinformation in Disasters	Drone Imagery Prediction & Surveying
Cash Disbursements	Flexible Funds	Mental Health & Trauma Care	Small Scale Disaster Funds and Support
Fast Scanning for Survivors			

3.2.3 Innovation in Disaster Response, Recovery and Resilience (IDR3) – Spring 2021 and Spring 2022

Innovation in Disaster Response, Recovery and Resilience (Sp21, Sp22) is a project-based course, sponsored by the National Security Innovation Network, that provided students an opportunity to work on challenges related to disaster response and management. The course flyer described the learning opportunity as follows:

> You'll apply design innovation methods in a semester-long project to real challenges in the disaster management space, which we've sourced in collaboration with the National Security Innovation Network. The course is

interdisciplinary, so bring your unique skills and perspective - no technical expertise required.

Furthermore, the IDR3 (Sp21, Sp22) course syllabus outlined the course description, desired outcomes and expectations as follows:

Course Description: In this class, you will practice framing and solving actionable, human-centered problems from a complex systems space: Disaster Response. Selecting from a range of pre-defined problem sets in the disaster response space, students spend the class immersed in a semester-long project to design a technology-based intervention that address specific needs identified through the process of the class. Students will develop fluency in key concepts in disaster response, while developing expertise in the following toolkits: design thinking, systems thinking, and emerging technologies. Interventions will be contextualized and rigorously assessed for their relevance as a technology-based venture and presented to a committee of stakeholders for feedback at the end of the course.

Desired Course Outcomes: Students can expect to depart the semester understanding customer-driven design and entrepreneurial methods, tools, and processes. They will also learn how to work in multidisciplinary teams to design technology solutions to disaster response challenges.

Potential problem spaces were sourced in collaboration with the National Security Innovation Network (NSIN) and selected from the pool of Department of Defense problems sourced for the Hacking4Defense program. The course instructor selected problems related to disaster preparedness, response, or resilience.

On the first day of class, students were provided a brief introduction to potential problem statements. As a homework assignment, students submitted their top three problem choices, as well as indicated one problem they would NOT be interested in working on before the next class meeting. All problem spaces offered for IDR3 (Sp21, Sp22) were assigned a student team, and are shown below.

Table 3: Course Projects Innovation in Disaster Response, Recovery, & Resilience (IDR3) – SP21

Problem Spaces Offered (Student team formed for all problem spaces)		
Data for Search and Rescue	Awareness of Personnel & Processes Post-Disaster	Preparing Air Assets for Disaster Response
Resilient & Robust Navigation	Digital Transformation of Moroccan Disaster Response Teams	Synchronizing Real-Time Data During Disasters

Table 4: Course Projects Innovation in Disaster Response, Recovery, & Resilience (IDR3) – SP22

Problem Spaces Offered (Student team formed for all problem spaces)

Managing Misinformation	Tracking and Connecting with Populations Post-Disaster	Training and Preparing Mobile Medical and Surgical Teams
Acclimatization to High Altitudes	Integrating Social Media Insights into Search and Rescue (SAR) Workflows	

3.2.4 Notable Differences Between Course Offerings

As can be expected with any new course offering, the course implementation varied with each subsequent offering, evolving based on lessons learned from the previous iteration(s). The detailed course descriptions for each iteration were provided in the sections above. This section discusses the course lineage and key differences between offerings.

The most significant change between offerings took place between the first and second iteration of the course with the transition from Hacking4Local:Oakland (Sp19) to Innovation in Disaster Response (Sp20). Three notable changes occurred between these two iterations:

(i) Change in Course/Problem Theme: The theme of problems sourced for the course changed from societal issues faced by city officials and local governments to problems focused on disaster response.

(ii) New Course Title: The course title was changed from "Hacking4Local:Oakland" to "Innovation in Disaster Response." With the intention to increase belongingness and attract a more diverse student population, "hacking," which may have a negative connotation, was removed from the course title and replaced with "innovation."

(iii) Shift in Pedagogical Approach: The pedagogical approach to teaching innovation and design shifted from the Lean Launchpad methodology to one utilizing innovation as a learning process anchored in design thinking and human centered design, as outlined by (Beckman & Barry, 2007). In all iterations of the course, stakeholder interviews were a central component to framing and reframing the problem, as well as developing and testing potential solutions.

The first two changes described are easily identifiable by students prior to enrolling in the course. Changes in the theme of the course and types of problems could potentially affect students' interest and motivation in enrolling in the course. The third change, while mentioned in the course description, is one that would be less apparent to students and, thus, could have had less of a potential impact on student enrollment. However, this change in pedagogical approach may affect students' overall experience with the course. While an interesting research question, a comparison and analysis of the two pedagogical approaches is not the focus of this research. This change is explicitly mentioned due to the potential impact this change may have had on students' experience with the course that could potentially be reflected in students' final reflections.

A less significant, but notable change regarding problem sourcing and problem theme took place between the second and third offering of the course with the transition from Innovation in Disaster Response (Sp20) and Innovation in Disaster Response, Recovery, and Resilience (Sp21). The following changes were incorporated during the final two iterations of the course (Sp21 and Sp22):

(i) Problem Sourcing and Project Sponsors: Problems for the course were sourced through the Hacking4Defense program from DoD project sponsors. The potential problem sets were carefully vetted by the course instructor to have a direct connection to disaster response, recovery, or resilience.

(ii) Expanded Course Theme and Title: The theme of problems sourced was expanded to include disaster resilience and the course title was updated accordingly.

Finally, a significant deviation between iterations of the course is the change in instructional modalities. Due to the COVID-19 pandemic and state-mandated lockdown, in Spring 2020 the course was abruptly transitioned to remote learning for the last four weeks of the course. Due to the continuing pandemic, the course was offered as a fully remote course for the entire duration of the semester in Spring 2021 and offered as a hybrid course in Spring 2022. The effects of the instructional modality are not within the scope of this research; however, the effects on students' learning experience are included to provide additional context to better understand students' perceived value from taking the course.

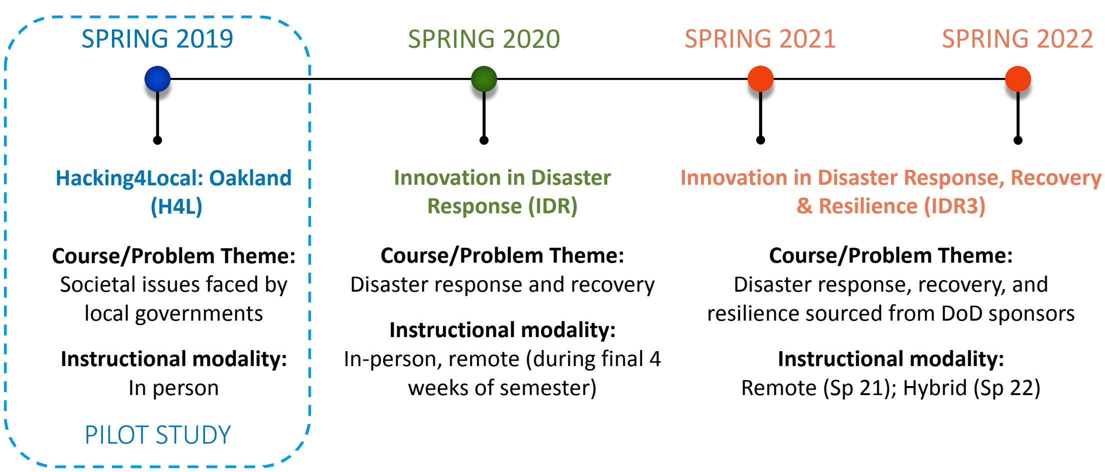


Figure 2: Variations Between Course Offerings

Due to the significant changes that took place between the Hacking4Local and subsequent iterations of Innovation for Disaster Response courses (IDR & IDR3), the Hacking4Local class served as the pilot study for this research. Coding and analysis of student motivations for taking the course, goals enumerated in the course and project goals survey, and students' final reflection responses enabled the development of the coding scheme used to code data collected from subsequent iterations of the Innovation in Disaster Response course (Sp20; Sp21; & Sp22).

3.3 Participants

All four course offerings (Hacking4Local:Oakland (Sp19), Innovation in Disaster Response (Sp20), and Innovation in Disaster Response, Recovery, and Resilience (Sp21 and Sp22)) 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 at the university, including Development Engineering, Mechanical Engineering, and Design Innovation.

Table 5: Course Listing Across Departments

Course	Development Engineering	Mechanical Engineering	Design Innovation
H4L (Sp19)	DevEng290 (CCN #19872) Enrolled students: 16	MecEng292C (CCN #33132) Enrolled Students: 2	
IDR (Sp20)	DevEng290 (CCN# 27940) Enrolled students: 16	MecEng292C (CCN# 33474) Enrolled students: 7	
IDR3 (Sp21)	DevEng290 (CCN# 19773) Enrolled students: 8	MecEng292C (CCN# 33379) Enrolled students: 16	DesInv190 (CCN# 15750) Enrolled students: 4
IDR3 (Sp22)	DevEng290 (CCN# 19385) Enrolled students: 6	MecEng292C (CCN# 33444) Enrolled students: 10	DesInv190 (CCN# 15509) Enrolled students: 5

The breakdown of students who applied for and enrolled in each course offering are shown in the tables below.

Table 6: Course Applications and Enrolled Students - Hacking4Local:Oakland (Sp19)

Course Applications: 52					
Gender		**Major/Discipline**		**Class Standing**	
Male	36	Engineering	19	Undergraduate	27
Female	16	Non-Engineering	33	Graduate	25
Enrolled Students: 19					
Gender		**Major/Discipline**		**Class Standing**	
Male	15	Engineering	8	Undergraduate	9
Female	4	Non-Engineering	11	Graduate	10

Table 7: Course Applications and Enrolled Students - Innovation in Disaster Response (IDR) - Sp20

Course Applications: 47					
Gender		Major/Discipline		Class Standing	
Male	18	Engineering	19	Undergraduate	15
Female	29	Non-Engineering	28	Graduate	32
Enrolled Students: 23					
Gender		Major/Discipline		Class Standing	
Male	10	Engineering	9	Undergraduate	7
Female	13	Non-Engineering	14	Graduate	16

Table 8: Course Applications and Enrolled Students - Innovation in Disaster Response, Recovery, & Resilience (IDR3) - Sp21

Course Applications: 37					
Gender		Major/Discipline		Class Standing	
Male	16	Engineering	25	Undergraduate	9
Female	21	Non-Engineering	12	Graduate	28
Enrolled Students: 29					
Gender		Major/Discipline		Class Standing	
Male	12	Engineering	21	Undergraduate	5
Female	17	Non-Engineering	8	Graduate	24

Table 9: Course Applications and Enrolled Students - Innovation in Disaster Response, Recovery, & Resilience (IDR3) - Sp22

Course Applications: 27					
Gender		Major/Discipline		Class Standing	
Male	16	Engineering	16	Undergraduate	7
Female	11	Non-Engineering	11	Graduate	20
Enrolled Students: 22					
Gender		Major/Discipline		Class Standing	
Male	14	Engineering	15	Undergraduate	4
Female	8	Non-Engineering	7	Graduate	18

3.4 Data Sources and Data Collection

The data sources collected to assess students' motivations for taking the course, students' goals they set for themselves for their project and the semester, and students' perceived value of the course are captured at different points in time with respect to students' engagement with the course. Data collection times range from before, during, and at the conclusion of the semester, as well as 1 to 3 years after the conclusion of the semester. The following timeline illustrates the different points in time that each data source was collected with respect to the semester. (Note: RQ is abbreviation for research questions.)

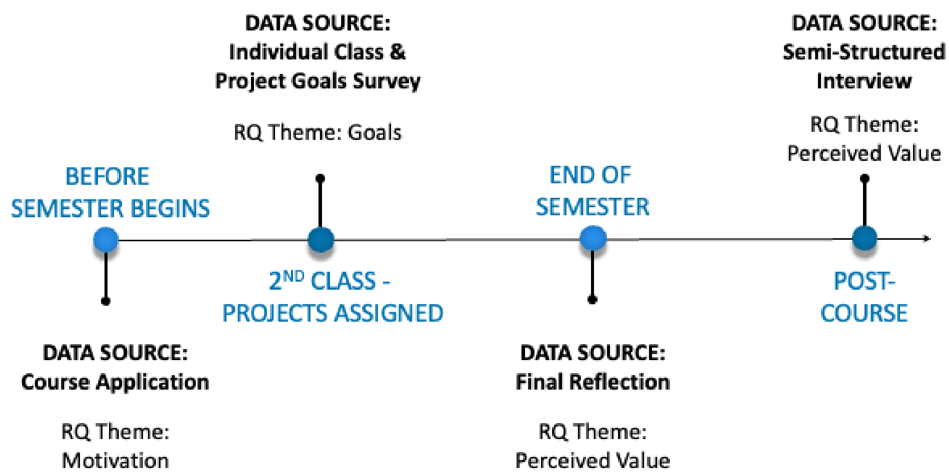


Figure 3: Data Collection Timeline Relative to Semester

For convenience, the research questions are repeated below to connect data sources with specific research questions.

RQ1: What motivates students to enroll in social-impact-driven, project-based elective courses?
RQ2: What goals do students set for themselves when working on social-impact-driven, collaborative projects?
RQ3: What do students value from social-impact-driven, project-based learning opportunities?
RQ4: How do social-impact-driven, project-based opportunities influence students' perspectives on their future goals?
RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?

The table that follows provides additional details about each data source, such as collection method and sample size, direct correlation with specific research themes and research questions, as well as analysis methods utilized. Hypotheses and anticipated outcomes for each data source are addressed in the following sections 3.4.1-3.4.4. Identified limitations for each data source are addressed in section 4.7.

Table 10: Overview of Data Sources and Intended Use

Research Questions	**DS-X: Data Source**	**Data Type, Sample Size**	**Data Analysis Methods**
<u>RQ Themes:</u> Motivation RQ1: What motivates students to enroll in social-impact-driven, project-based elective courses? RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?	DS-1: <u>Course Application</u> <u>H4L:</u> "Why are you interested in taking this class?" / "What skills do you hope to gain or sharpen through taking this class?" <u>IDR/IDR3</u>: 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?	<u>Data Type:</u> Short response (Google form) <u>Sample Size</u>: 163 applicants H4L (Sp19): 52 IDR (Sp20): 47 IDR3 (Sp21): 37 IDR3 (Sp22): 27	Content/ Document Analysis
<u>RQ Themes:</u> Goals RQ2: What goals do students set for themselves when working on social-impact-driven, collaborative projects? RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?	DS-2: <u>Individual Class and Project Goals Survey</u> "What goals do you have for the semester/project?"	<u>Data Type:</u> Short response (in-class/Google form) <u>Sample Size:</u> 300 responses H4L (Sp19): 76 IDR (Sp20): 86 IDR3 (Sp21): 72 IDR3 (Sp22): 66	Content/ Document Analysis

<u>RQ Themes:</u> Perceived value, future goals RQ3: What do students value from social-impact-driven, project-based learning opportunities? RQ4: How do social impact-driven, project-based opportunities influence students' perspectives on their future goals? RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?	DS-3: <u>Final Reflection</u> Reflection prompt: 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? • 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?	<u>Data Type:</u> Long response (500-750 words), reflection prompt <u>Sample Size:</u> 89 reflections H4L (Sp19): 18 IDR (Sp20): 22 IDR3 (Sp21): 29 IDR3 (Sp22): 20	Content/ Document Analysis
<u>RQ Themes:</u> Perceived value, future goals RQ3: What do students value from social-impact driven, project-based learning opportunities? RQ4: How do social impact-driven, project-based opportunities influence	DS-4: <u>Post-Course Semi-Structured Interview</u> A portion of these interview questions have been adapted from a longitudinal study investigating what alumni value from new product development education (Cobb et al., 2016). • 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/Spring 2021/Spring 2022?	<u>Data Type:</u> Semi-structured interview <u>Sample Size:</u> 12 interviews (average 27 minutes) IDR (Sp20): 5 IDR3 (Sp21): 2 IDR3 (Sp22): 5	Narrative Analysis

students' perspectives on their future goals? RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?	• 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 prepare you to better understand or identify potential career paths for yourself? • From your experience in industry to date, how would you change the course to help better support/prepare current students in their careers?		

3.4.1 DS-1: Course Application – Student Motivations

Prior to the start of the semester, students interested in taking the course completed a course application (completed via Google form). In relation to RQ1: "What motivates students to enroll in social-impact-driven, project-based elective courses?" the course application included a short response question specifically asking students to write a few sentences establishing their interest and motivation to join the class. Students' responses to the following prompt on the course application (DS-1) served as the data source to evaluate students' motivation for taking the course.

> MOTIVATION PROMPT: 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?

In addition to the motivation open response question, the course application asked students to list, if any, innovation-related classes previously taken; to rate their prior experience in skills such as programming, UI/UX design, Microcontroller programing, AR/VR, Makerspace skills, Design Thinking, Systems Thinking, Business Model Development and Evaluation, Statistics and Data, Machine Learning/AI Methods; and to assess their prior experience working in intensive project-based environments.

The total sample size available for DS-1 includes responses from 163 applicants (H4L (Sp19) - 52 applicants; IDR (Sp20) - 47 applicants; IDR3 (Sp21) - 37 applicants; IDR3 (Sp22) - 27 applicants). However, since this research focuses on students who enrolled and completed the course, only course application responses from students who ended up enrolling in the course are included in the data set. The sample size for DS-1 included in this research is responses from 90 enrolled students (H4L (Sp19) - 19 students; IDR (Sp20) - 23 students; IDR3 (Sp21) - 26 students; IDR3 (Sp22) - 22 students).

Evaluating course application responses for students who applied for the course but did not enroll could also provide interesting insight into students' motivations. While this analysis was not included as part of this study, it is briefly discussed in Section 5.3 as potential future research.

3.4.1.1 Hypotheses and Anticipated Outcomes

Evaluating students' responses to their motivation for taking the course in the course application can provide insight into the learning outcomes and opportunities that students are seeking when selecting among available elective courses. Given that student motivation can serve as a driver for choice, persistence, and performance in engineering (Kirn & Benson, 2018; Mamaril et al., 2016), such insights can inform both curriculum development and the dissemination of course information to students about the course.

It is important to note that students' responses to their motivation for taking the course are severely limited by the course information available to the student during the time of registration. Information available to students about the course included: (i) a brief course description, (ii) a 30-minute informational webinar (if students attended), (iii) and for subsequent course offerings (IDR-Sp20; IDR3-Sp21; IDR3-SP22) a website showcasing student final projects from previous years.

3.4.2 DS-2: Individual Class and Project Goals Survey – Student Goals

In relation to RQ2: "What goals do students set for themselves when working on social-impact-driven, collaborative projects?" students were asked to share three or more goals based on the following prompt after project assignments were announced. These responses (DS-2) served as the data source to evaluate the goals that students set for themselves.

> <u>GOALS PROMPT:</u> What are your individual goals for the semester and your project? Please list three goals you have for this semester and your project. These goals can be desired class/project outcomes and/or desired team experiences. You can tie these to the individual goals specified in your collaborative plan from this week's class.

To facilitate matching students to their preferred project assignments, students were introduced to all available problem spaces during the first class meeting with a brief problem statement and information about the project sponsor. Problem spaces offered for each course offering are listed in Sections 3.2.1-3.2.3. Following the introduction to the available problem spaces students were asked to complete the project preference survey indicating their top three project preferences and list one project they did NOT want to work on (if any) before the next meeting.

During the second class meeting, students' project and team assignments were announced. Students had an opportunity to meet and learn more about their team members through sharing the personal profile activity that had been assigned as homework during the first class meeting. After team and project assignments were announced and team member introductions were completed, students were asked to write three or more goals they had for themselves and their project. In the Hacking4Local (Sp19), students wrote several individual goals they had for the project and the semester on Post-it Notes. The Post-it Notes were collected, and students' responses were transcribed. In subsequent course offerings, Innovation in Disaster Response (Sp20) and Innovation for Disaster Response, Recovery, and Resilience (Sp21 and Sp22), students' goals were collected though the completion of the goals survey (Google form).

The sample size for DS-2 includes 300 goals responses total (H4L (Sp19) - 76 goals; IDR (Sp20) - 86 goals; IDR3 (Sp21) - 72 goals; IDR3 (Sp22) - 66 goals).

3.4.2.1 Hypotheses and Anticipated Outcomes

At the time this data is collected, students have more information about the course and what to expect for the duration of the semester. The course syllabus outlining the progression of the semester and the project they will be working on for the duration of the semester are more tangible items for students to assess personal goals they would like to achieve through participating in the course and project. As students have more information, their responses can start to become more specific. For example: "I'd like to learn more about Cash Disbursement post disaster."

3.4.3 DS-3: Final Reflection – Student Perceived Value

In relation to RQ3: "What do students value from social-impact driven, project-based learning opportunities?" and RQ4: "How do social impact-driven, project-based opportunities influence students' perspectives on their future goals?", students were asked to share 500- to 700-word reflection to the following prompt as part of the final deliverables for the course. These final reflections (DS-3) served as the data source to evaluate the students' perceived value from participating in the course.

> REFLECTIVE PROMPT: Describe your personal learning—shifts in mindsets, development of skill sets, 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?
> - 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?

Submission of the final reflection coincided with additional final team deliverables to be submitted after the Course Project Showcase, which was scheduled for the final week of the semester. Final team deliverables to be submitted included the team's final developed prototype, team presentation for the Course Project Showcase, and a 2-minute video illustrating the team's semester-long journey from problem framing and re-framing, to ideation and solution development, to prototyping and experimenting.

The sample size for DS-3 includes 89 reflections (H4L (Sp19) - 18 reflections; IDR (Sp20) - 22 reflections; IDR3 (Sp21) - 29 reflections; IDR3 (Sp22) - 20 reflections).

3.4.3.1 Hypotheses and Anticipated Outcomes

Once the semester is over, students can assess what they learned and valued from the course in a more holistic manner. The final reflection is often the final deliverable of the course, after all other high-stake deliverables, such as final presentations and prototype submissions. There is often a sense of accomplishment and relief, especially if teams received positive feedback and affirmation of the success of their solutions from external partners such as their project sponsors.

Some misalignments between students' motivations and goals reported at the beginning of the semester and perceived value reported at the end of the semester may stem from the additional learning opportunity arising from working on the project itself. The project experience–collaborating with team members, navigating multiple project requirements, engaging with project sponsors and other stakeholders, etc., is a learning experience itself. As such, the complete experience affords a variety of opportunities for the development of less tangible skill sets, such as project management skills or improved communication skills, that may not initially come to mind when students are assessing the different learning opportunities that the course/project could potentially provide them throughout the semester.

3.4.4 DS-4: Post-Course Semi-Structured Interviews – Student Perceived Value (longitudinal)

In relation to RQ3: "What do students value from social-impact driven, project-based learning opportunities?" and RQ4: "How do social impact-driven, project-based opportunities influence students' perspectives on their future goals?"; the focus was on how these perspectives might change as students progress in their professional careers beyond the course. To gather such information, a series of 30-minutes interviews were conducted (using the following interview protocol) with students 1 to 3 years after completing the course. These post-course, semi-structured interviews (DS-4) served as a data source to evaluate the students' longitudinal perceived value from participating in the course.

INTERVIEW PROTOCOL: Interviews were conducted using a video conferencing platform and students were asked the following questions:

- 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/Spring 2021/Spring 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 support/prepare current students in their careers?

An email requesting a 30-minute post-course follow-up interview was sent to 74 students who participated in Innovation for Disaster Response (Sp20) or in Innovation in Disaster Response, Recovery, and Resilience (Sp21 and Sp22). Emails were sent to email addresses on file for each student at the time of their enrollment in the course; all of these emails were .edu email addresses from the university. Of the 74 emails sent, three were undeliverable. Students interested in participating were asked to book a 30-minute slot from during a two-week window of available appointments.

The sample size for DS-4 includes 12 semi-structured interviews (IDR (Sp20) - five interviews reflections; IDR3 (Sp21) – two interviews; IDR3 (Sp22) – five interviews), each ranging in duration from 30 to 45 minutes. All interviewees consented to video recording.

3.4.4.1 Hypotheses and Anticipated Outcomes

Many studies have evaluated what alumni value from their academic programs after moving on to work in industry (Cobb et al., 2016; Lattuca et al., 2014; Martin et al., 2005; Passow, 2012). For example, in a study evaluating progress towards the Engineer of 2020 goals, (Lattuca et al., 2014) report that a survey of 1,380 alumni (3 years post-graduation) concluded that written and oral communication skills, teamwork, and professional skills were all rated as being very highly important to their current work.

As students gain experience working in professional environments, students gain opportunities to evaluate and assess the value of skillsets they developed/learned with respect to what they need in their professional practice. Interviewing students who have started working in industry since taking the course may provide a unique perspective into what students perceive as valuable from the course and how this may change from the perceived value at the completion of the course.

3.5 Methodology

Reflexive thematic analysis is an interpretative approach to qualitative data analysis to identify, analyze, and interpret patterns across a qualitative dataset (Braun & Clarke, 2006, 2019; Braun, Virginia; Clarke, 2021; Byrne, 2022; Kiger & Varpio, 2020). Initially wide used in psychology (Braun & Clarke, 2006), it has become widely used in a wide range of social science research fields, such as qualitative sport and exercise research (Braun & Clarke, 2019), health professional education (Byrne, 2022; Kiger & Varpio, 2020), and engineering education (Hess et al., 2021). Hess et al. (2021) analyzed students' written ethical reflections following a rodent tissue harvesting lab as part of an introductory biomechanics course. Using reflexive thematic analysis, Hess et al. (2021) reviewed individual student reflection to inductively develop and refine codes to study empathy and ethical becoming in first year biomedical engineering students.

Reflexive thematic analysis is flexible qualitative data analysis method appropriate for "seeking to understand experiences, thoughts, or behaviors across a data set" (Kiger & Varpio, 2020, pg. 846). Using reflexive thematic analysis, themes can be inductively or deductively generated. Key components of reflexive thematic analysis include (i) familiarizing oneself with the data, (ii) generating of initial codes, (iii) identifying of initial themes, (iv) testing initial themes developed across the larger dataset to ensure, and lastly (v) refining, defining, and naming themes (Byrne, 2022; Kiger & Varpio, 2020).

3.5.1 Identification of Patterns and Themes in Student Data using Reflexive Thematic Analysis

Hacking4Local:Oakland (Sp19) served as the pilot study for this research. The first group of data coded from this course were students' goals collected as part of the Individual Class and Project Goals Survey (DS-2: H4L-Sp19). More information about the Individual Class and Project Goals Survey DS-2 is provided in Section 3.4.2. A total of 76 different responses from 20 students were generated as part of the Individual Class and Project Goals Survey (DS-2: H4L-Sp19).

3.5.1.1 Emerging Themes and Codes in Pilot Study Data (H4L-Sp19)

Using a reflexive thematic analysis approach, preliminary codes were inductively generated and assigned based on initial patterns recognized. With this initial review of student goals reported, three main themes for students' goals were identified: (i) action-oriented/application of previous knowledge goals, (ii) acquisition of new knowledge/new learning opportunity goals, and (iii) career/outcome-oriented goals. These main themes were identified by noticing patterns in codes that were generated when reviewing the data. The initial themes and sub-theme codes generated, and sample responses for each code are shown in the following table.

Table 11: TH-1 Initial Themes, Codes, Sample Responses - Goals (DS-2: H4L-Sp19; n=76, 20 students)

Theme	Code/Sub-Theme	Sample Responses	Quantity	
Action/Application of	Greater good/Real-world	Help my town Work on meaningful project To give back to the Bay Area	10	13

		Influence a culture of justice in the Bay Area		
	Apply previous learning/ domain specific content knowledge to a real-world problem	Applying computer science to a local problem Apply my skillsets as a dev practitioner to a new context	3	
Acquire New Knowledge/ New Learning Opportunities	Project Specific/Domain specific content learning	Understand how we can design transportation system from public POV Public health program design Learn more about the wildfire problem	15	39
	Non-domain specific learning	Non-engineer type projects Engage and learn from others and their disciplines	3	
	Business/Start-up/Product Design Content Learning	Learn more about the lean mentality Interact with experts in product design Learn to get feedback from the people for whom we are designing product	8	
	Professional skillset (practice) development	Develop project management skills To improve teamwork and communication skills To gain experience reaching out into the real world and interacting with professionals	13	
Career/ Outcome Oriented	Career advancement/ Networking	Connections Have project to include in portfolio Line on resume	7	8
	Commercialize solution/Start a company	Launch a product to market, ideally	1	

These initial themes generated were reviewed against other data collected during H4L (Sp19), specifically the Course Application (DS-1: H4L-Sp19) and Final Reflection (DS-4: H4L-Sp19). These additional data sets were coded using the initial codes generated from students' goals to determine how well codes and themes generated identified and captured the themes from a larger data set. After coding the additional data sets, two additional codes (indicated in gray) were added and the student goal data (DS-2: H4L-Sp19) was recoded, shown below.

Table 12: TH-2 Revised Themes, Codes, Sample Responses – Goals (DS-2: H4L-Sp19; n=76, 20 students)

Theme	Code/Sub-Theme	Sample Responses	Quantity	
Action/Application of Previous	Greater good/Real-world	Help my town Work on meaningful project Give back to Bay Area Influence a culture of justice in the Bay Area	10	13

	Apply previous learning/ domain specific content knowledge to a real-world problem	Applying computer science to a local problem Apply my skillsets as a dev practitioner to a new context	3	
Acquire New Knowledge/ New Learning Opportunities	Project specific content learning	Understand how we can design transportation system from public POV Public health program design Learn more about the wildfire problem	15	46
	Business/Start-up/ Product Design Content Learning	Learn more about the lean mentality Interact with experts in product design Learn to get feedback from people we design product for	9	
	Professional skillset development	Develop project management skills Improve teamwork and communication skills Be able to learn how to navigate differences and use them to the advantage of the team	14	
	Mindset development	Understand how to navigate complexity Be able to think beyond the problems I have solved before Gain skills to understand issues and structure solutions	8	
Career/ Outcome Oriented	Final product to showcase/ Tangible outcome	Have project to include in portfolio Graduate with kick-ass project work	4	12
	Career advancement/ Networking	Connections Help me get a job in design	7	
	Commercialize solution/ Start a company	Launch a product to market, ideally	1	

These updated themes and codes were then tested once again using the data collected as part of the Individual Class and Project Goals Survey the following year (DS-2: IDR-Sp20), described below.

3.5.1.2 Refinement of Themes and Codes using Additional Course Data (IDR-Sp20)

With the goal of further testing the emerging themes and codes generated, the codes developed were used to code data collected from IDR (Sp20). After coding data collected from the Individual Class and Project Goals Survey (DS2: IDR-Sp20) using the existing coding scheme, themes and codes were reevaluated and updated. The revised coding scheme (indicated by the gray background) and recoded student goal data (DS-2: IDR-Sp20) are shown below.

Table 13: TH-3 Revised Themes, Codes, Sample Responses – Goals (DS-2: IDR-Sp20; n=86, 22 students)

Theme	Code/Sub-Theme	Sample Responses	Quantity	
Action/Application of Previous Knowledge	Greater good/Real-world	Do something good Have fun working a real-world challenge	3	3
	Apply previous learning/ domain specific content knowledge to a real-world problem		0	
Acquire New Knowledge/ New Learning Opportunities	Project specific content learning	Learn more about cash as a disaster response tool Learn drone stuff Find out more about the systems that exist to help during emergencies	17	45
	Technical skill set development	Learn about data science, ML, AR/VR Image classification techniques	8	
	Professional skill set development	Refine team skills Project management	9	
	Mindset development	Learn the basis of user experience design Learn and practice the design process How to shape tech to respond to community needs	11	
Career/ Outcome Oriented	Final product to showcase/Tangible outcome	Achieve a UX product to put in my portfolio Have project that I'm proud of and that I can share Pass the class and get credits	9	14
	Career advancement/ Networking	Networking Make connections with people in the field	4	
	Career Option Exploration	Consider possible career path in disaster response and building resiliency	1	

The emerging themes and codes were tested one final time by coding students' Final Reflections (DS-4: IDR-Sp20) using the revised coding scheme. After coding this additional data set, the emerging codes were updated one final time and collapsed into the main themes. Given the long timespan (before, during, and after the course) in which data are collected from students, themes were generalized to include both responses related to development and application of skill sets. Students' goals (DS-2: IDR-Sp20) were re-coded using the final themes developed and are shown below.

Table 14: TH-4 Final Themes, Sample Responses – Goals (DS-2: IDR-Sp20; n=86, 22 students)

Theme	Sample Responses
Theme 1: Develop/apply technical skill sets and content knowledge	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).

	Learn the basis of user experience design knowledge
Theme 2: Develop/apply professional skill sets	Become a better team player working with multiple disciplines Still like my group by the end of the project Refine my team skills
Theme 3: Develop/apply design skills/processes	Learn how to take a step back and see the larger framework of problem solving Ideate both tech-related and non-tech solutions
Theme 4: Achieve impact-oriented outcome	Do something good Utilize [University Name] resources to fight climate change Achieve a UX product and put it in my portfolio Have project that I'm proud of and that I can share Pass the class and get credits
Theme 5: Journey for career clarity	Consider possible career path in disaster response and building resiliency I am committed to design products and services that can make a good impact on humans. I am currently applying to another master's degree in HCI with a focus on human-centered design and I believe this course can help me explore more on this path.

3.6 Development of Codebook

Through reflexive testing of emerging themes with various data sets, the emerging themes from student data collected at various times with respect to engagement in the course were finalized. With the emerging themes finalized, two researchers familiar with all three offerings of the Innovation for Disaster Response (Sp20) and Innovation in Disaster Response, Recovery, 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 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 included in the table that follows. Details about the inter-rater reliability achieved and Cohen's Kappa metric for agreeability between coders is provided in Section 3.6.1.

Table 15: Final Codebook: Themes, Subcodes, Sample Responses

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.	Subcode 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)."
		Subcode 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"
		Subcode 3	**Problem-specific** knowledge and skills (e.g., content knowledge related to a specific problem space, such as cash transfer 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.	Subcode 1	**Teamwork/Interpersonal Skills**	"Each of my teammates had a specific skill that really translated well into our final deliverable, be it graphics design or just a general sense of aesthetics. It was great to get different perspectives on how they consider different things and all of this not from the engineering perspective." "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"
		Subcode 2	**Communication Skills**	"Improve my communication skills." "Learn how to constructively communicate feedback to improve ideas (w/o being rude and sapping energy)."

		Subcode 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." "I learned that I do pretty well with communication, organization, and time management when it comes to working with multiple stakeholders in different time zones."
		Subcode 4	**Project Management and Leadership Skills**	"develop skills necessary to execute the project effectively" "I want to be able to be proud of my project and develop my project management skills."
		Subcode 5	**Client Engagement / Relationship Skills**	"Working with sponsors on more systematic problems was something I had never experienced before. As such I feel like most of my learning this semester came from that side of the project – sponsor management and systems thinking." "…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).	Subcode 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."

		Subcode 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." "I love to learn about different ways to frame and think about problems"
		Subcode 3	**Ideation and Solution Development**	"Ideate both tech-related and non -tech solutions"
		Subcode 4	**Prototyping and Experimentation**	"The range of prototypes I imagine possible in design classes has undoubtedly been expanded due to IDR3." "…and outlining functional, representational and integrated prototypes based on feasibility, viability and desirability."
		Subcode 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 that what we think would be a cool gadget to design that might not be as helpful to them."
		Subcode 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."
	The desire to work on a meaningful project or	Subcode 1	**Product / Project Outcome:** building something tangible	"Develop a method/device with my team that can help positioning under debris when GPS is not available."

Theme 4: Achieve impact-oriented outcome	achieve an impact-oriented outcome.			"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."
		Subcode 2	**Academic Outcome:** help me succeed in school	"Pass the class and get credits." "As a mechanical engineer pursuing a certificate in design, this course fulfills the Advanced Design criteria"
		Subcode 3	**Professional Outcome:** help me succeed in career	"I feel this course will make me evolve as a designer." "Achieve a UX product and put in my portfolio." "I just applied to a job at a human-centered cybersecurity firm, and I know that I will use examples from this class if I get an interview."
		Subcode 4	**Change Outcome**: Doing good	"Do something good." "Utilize [University Name] resources to fight climate change." "I'm particularly excited about expanding my design process skills while working on a project that matters." "Specifically, in the pandemic we're experiencing today, compounded with the natural disasters we face across the globe like tornadoes, earthquakes, and hurricanes--this topic connects with my personal goals because I know this topic is highly relevant for everyone, and being able to work with a diverse team to create a solution for this would be an honor for me. " "Over the duration of this course, being able to prototype something really tangible that could help NTSB investigators document aircraft crashes and listening to all the guest speakers inspired me to try and

				apply my technical skills to important issues throughout the world today. "
Theme 5: Journey for career clarity	Clarity regarding future professional goals and/or paths.	Subcode 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."
		Subcode 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. At the end of the semester, designing the UX interface as well as the brochure became more of a task and I felt like it wasn't something I could do for years to come. In that process I was constantly thinking about the interviews and hearing stories rather than worrying about the visual design."
		Subcode 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."
		Subcode 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. Listening to stories about the work out there and the up-and-coming developments inspired me to seriously consider this in my job search."

3.6.1 Inter-Rater Reliability and Measure of Agreement Between Coders

Inter-rater reliability was tested through an iterative process of coding responses, comparing codes applied, reconciling disagreements, and updating the codebook as necessary, with approximately 25% of the total data set including the course applications (DS-1), goals survey (DS-2), and final reflections (DS-3) collected from IDR (Sp20), IDR3 (Sp21), and IDR3 (Sp22). Inter-rater reliability for each of these instances is shown in the table that follows. After three rounds, an inter-rater reliability of 94% with approximately 28% of the data set was achieved between two raters. In total, 19 course applications (DS-1) out of 52 applications, 53 goals responses (DS-2) out of 209 goals responses, and 18 final reflections (DS-3) out of 68 reflections were included in the inter-rater reliability testing.

Table 16: Inter-Rater Reliability Results (18% of data; DS-1: n=11; DS-2: n=37; DS-3: n=12)

	Dataset Coded	Rater	# of Codes Applied	Agreements	Disagreements	Inter-Rater Reliability
ROUND 1	5% of dataset	Rater 1	25	286	29	90.8%
	DS-1: 4					
	DS-2: 8	Rater 2	23			
	DS-3: 3					
ROUND 2	5% of dataset	Rater 1	26	310	20	93.9%
	DS-1: 4					
	DS-2: 8	Rater 2	25			
	DS-3: 3					
ROUND 3	18% of dataset	Rater 1	154	1245	75	94.3%
	DS-1: 11					
	DS-2: 37	Rater 2	130			
	DS-3: 12					

In addition to assessing inter-rater reliability as the percentage of codes applied in agreement by both raters, the Cohen's Kappa value, which also takes into consideration the possibility of both coders agreeing by chance, was calculated for each code. Reviewing the Cohen's Kappa values for each code for each iteration of inter-rater reliability testing allowed coders to identify specific codes that required more detailed or nuanced definitions; the codebook was updated accordingly. The Cohen's Kappa values and corresponding interpretation for agreeability for each code achieved during Round 3 of inter-rater reliability testing is shown below. After three rounds of iterative inter-rater reliability testing, both coders were in near perfect agreement for 20 codes, substantial agreement for one code, and moderate agreement for one code.

The lowest Cohen's Kappa value achieved was for the Design Thinking/Human-Centered Design code (κ=0.60, moderate agreement). Although a Cohen's Kappa value of 0.60 is interpreted as moderate agreement, it is at the high boundary of moderate agreement

($0.41 \leq \kappa \leq 0.60$). Additionally, this specific code was a new code added to the codebook during the inter-rater reliability testing to reconcile some of the nuanced differences in interpretation of codes that surfaced. This code was added for Round 2 of inter-rater reliability testing and refined for Round 3 of inter-rater reliability testing. After reviewing, discussing, and reconciling each instance, both raters were in moderate agreement for this code for Round 3, the codebook was refined and the remaining data were coded by a single coder.

Table 17: Cohen's Kappa Values and Interpretation (18% of data; DS-1: n=11; DS-2: n=37; DS-3: n=12)

Theme	Code	Cohen's Kappa, κ	Interpretation
Theme 1: Develop/apply technical skill sets and content knowledge	Discipline-Specific Knowledge and Skills	0.93	near perfect agreement
	Course Technology-Specific Knowledge and Skills	0.87	near perfect agreement
	Problem-Specific Knowledge and Skills	0.63	substantial agreement
Theme 2: Develop/apply professional skill sets	Teamwork / Interpersonal Skills	0.87	near perfect agreement
	Communication Skills	0.93	near perfect agreement
	Time Management Skills	0.97	near perfect agreement
	Project Management and Leadership Skills	0.90	near perfect agreement
	Client Engagement / Relationship Skills	0.97	near perfect agreement
Theme 3: Develop/apply design skills / processes	Research, Interviewing, and Data Collection	0.97	near perfect agreement
	Frame and Reframe Problem	0.93	near perfect agreement
	Ideation and Solution Development	0.90	near perfect agreement
	Prototyping and Experimentation	0.93	near perfect agreement
	Design Thinking / Human-Centered Design	0.60	moderate agreement
	Systems Thinking	0.90	near perfect agreement
Theme 4: Achieve impact-	Product / Project Outcome	0.83	near perfect agreement
	Academic Outcome	0.97	near perfect agreement

oriented outcome	Professional Outcome	0.87	near perfect agreement
	Change Outcome	0.83	near perfect agreement
Theme 5: Journey for career clarity	Type of Role	1.00	perfect agreement
	Type of Work / Project	0.83	near perfect agreement
	Type of Organization / Team	0.97	near perfect agreement
	Professional Values	0.90	near perfect agreement

Chapter 4 Results and Discussion

4.1 Descriptive Statistics: Course Applicants and Enrolled Students

Course applicants and enrolled students for each iteration of the course are analyzed below. Although the number of course applicants decreased with each iteration of the course, the number of enrolled students increased (the one exception was IDR3 (Sp22)). It is also important to note that the percentage of course applicants who enrolled in the course increased each year (36.5% H4L-Sp19; 48.9% IDR-Sp20; 78.4% IDR3-Sp21; 81.5% IDR3-Sp22). As described in Chapter 3, the first iteration of the course, Hacking4Loacl:Oakland (Sp19), served as the pilot study for this research. Course applicants and enrolled students for this course are included in the descriptive statistics; however, only data from the subsequent course offerings (IDR-Sp20, IDR3-Sp21, IDR3-Sp22) are evaluated and analyzed.

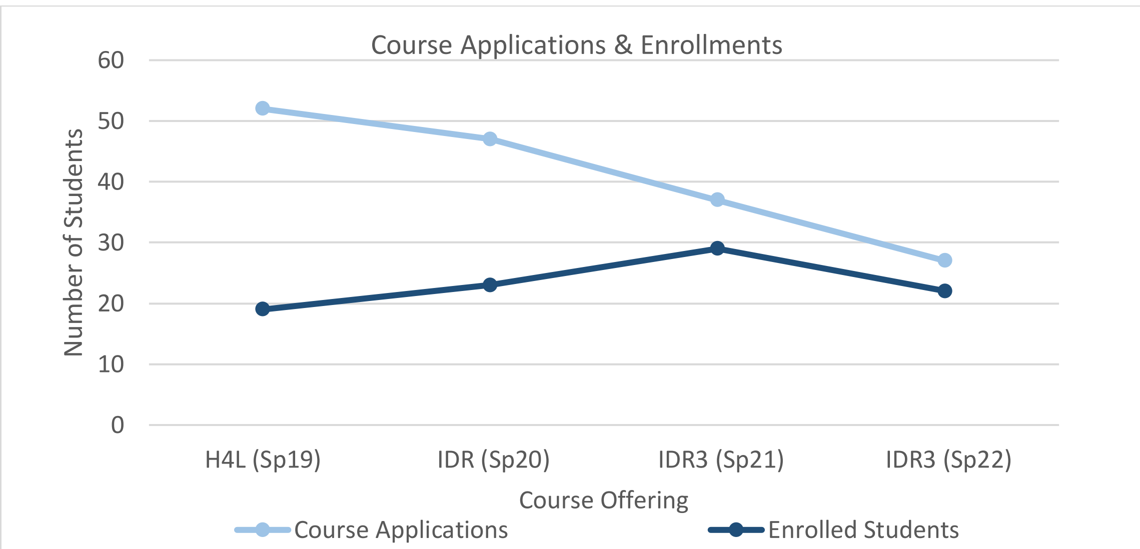
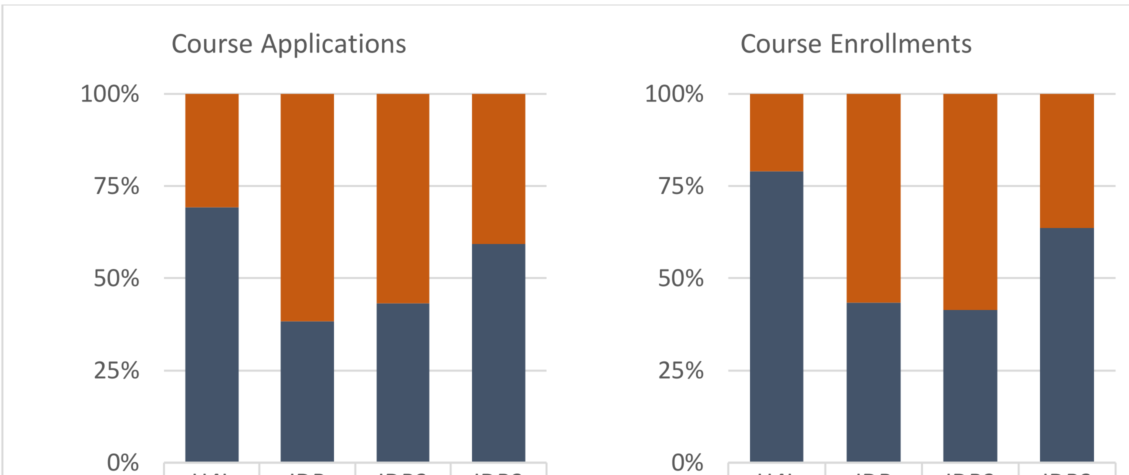


Figure 4: Course Applications and Student Enrollment

To enable further analysis of students who expressed interest in the course by submitting a course application and those who eventually enrolled in the course, course applications were coded for gender (male/female), discipline (engineering/non-engineering), and class standing (graduate/undergraduate). Gender was coded by the researcher, and discipline and class standing was coded based on student-provided responses in the course application.

4.1.1 Course Applicants and Enrolled Students – by Gender

Female students made up only 31% of the course applicants and 21% of the enrolled students for H4L (Sp19). Noting the lack of gender diversity in this course and reflecting that “hacking” may have a negative connotation and be less appealing to a diverse group of students, the course instructors intentionally updated the course title, removing the word “hacking.” The impact that the course title may have had on student interest and enrollment was not directly investigated; however, female student representation in subsequent iterations of the course increased. Female students were the majority of course applicants in Sp20 (62%) and Sp21 (57%); female students also formed the majority of enrolled students in Sp20 (57%) and Sp21 (59%).



Course Applications

	H4L (Sp19)	IDR (Sp20)	IDR3 (Sp21)	IDR3 (Sp22)
Female	16	29	21	11
Male	36	18	16	16

Course Enrollments

	H4L (Sp19)	IDR (Sp20)	IDR3 (Sp21)	IDR3 (Sp22)
Female	4	13	17	8
Male	15	10	12	14

Figure 5: Breakdown of Course Applicants and Enrolled Students – by Gender

4.1.2 Course Applicants and Enrolled Students – by Discipline

Each of the four course offerings was advertised as an interdisciplinary course and course information was shared across many departments. Additionally, all courses were cross-listed under Development Engineering, Mechanical Engineering, and Design Innovation (IDR3-Sp21, Sp22 only). To encourage enrollment from an interdisciplinary group of students, the course flyer that was circulated across multiple departments for the IDR & IDR3 courses included statements like: “All disciplinary backgrounds welcome - no technical experience is required!” (IDR-Sp20) and “The course is interdisciplinary, so bring your unique skills and perspective - no technical expertise required.” (IDR3-Sp21, Sp22).

All four course offerings attracted students from a variety of disciplines, including Engineering, Environmental Economics and Policy, Law, Business, Public Health, City Planning and Cognitive Science, to name just a few. To better understand the breakdown of students with technical and non-technical backgrounds, discipline reported in the course applications was coded as engineering or non-engineering. Students reporting dual majors, one technical and one non-technical (e.g., EECS and History), were coded as engineering. During the first two iterations of the course—H4L (Sp19) and IDR (Sp20)—the majority of course applicants and enrolled students came from non-engineering disciplines. However, for the last two iterations of the course—IDR3 (Sp21 and Sp22)—the majority of course applicants and enrolled students were engineering students.

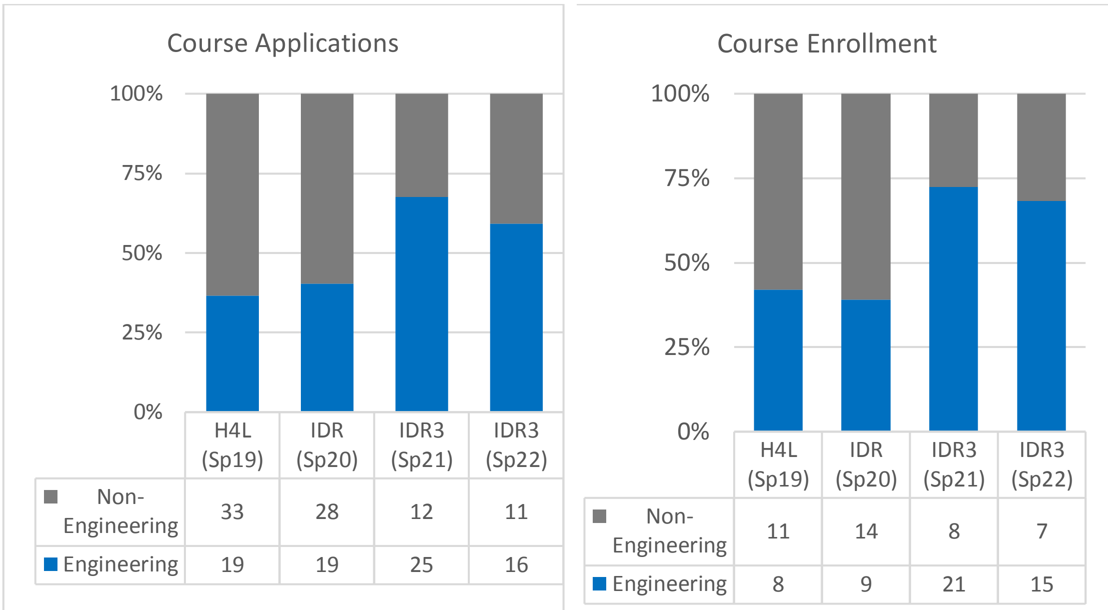


Figure 6: Breakdown of Course Applicants and Enrolled Students – by Discipline

4.1.3 Course Applicants and Enrolled Students – Engineering Students by Gender

Looking specifically at the breakdown of engineering students who applied and those enrolled in the class, female engineering student representation for each course offering is slightly less than the representation of all female students in the class. Social-impact-driven learning opportunities such as PBSL courses (A. Bielefeldt et al., 2009) and social entrepreneurship courses (Cobb et al., 2008) have been shown to result in higher participation by female engineering students, compared to their representation in engineering overall. With the exception of H4L (Sp19), course applicants and enrolled students in the IDR course series (Sp20, Sp21, Sp22) showed similar results. Female engineering students made up a good portion of course applicants and enrolled students. Most notable is the gender diversity achieved in the third offering of the course, IDR3 (Sp21).

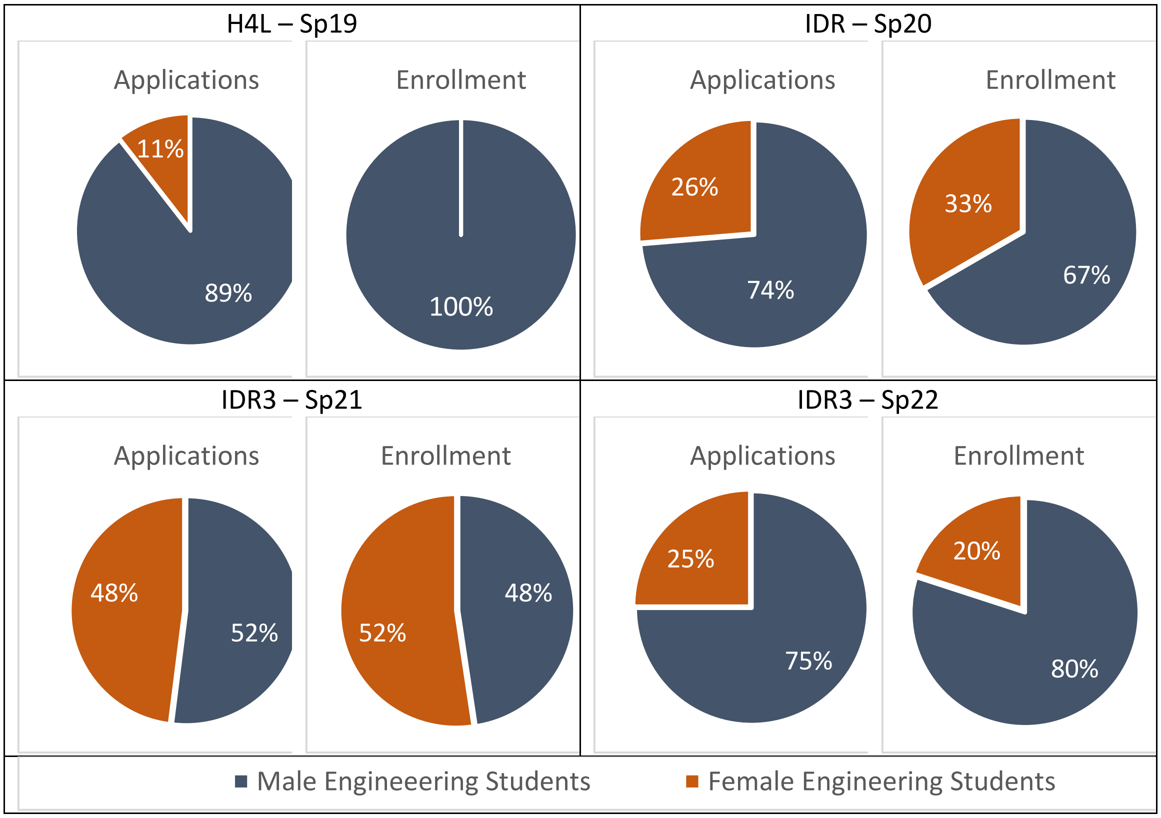


Figure 7: Breakdown of Engineering Student Applicants & Enrolled Students – by Gender

4.1.4 Course Applicants and Enrolled Students – by Class Standing

While the student populations who applied for and enrolled in H4L (Sp19) were split almost evenly between undergraduate students (applied: 52%; enrolled: 47%) and graduate students (applied: 48%; enrolled: 53%); graduate students made up a significant portion of students who applied for and enrolled in IDR (Sp20) and IDR3 (Sp21 & Sp22). Considering that much of the PBSL literature published to date investigates PBSL opportunities for undergraduate students, this research provides a unique contribution regarding graduate students and PBSL learning opportunities.

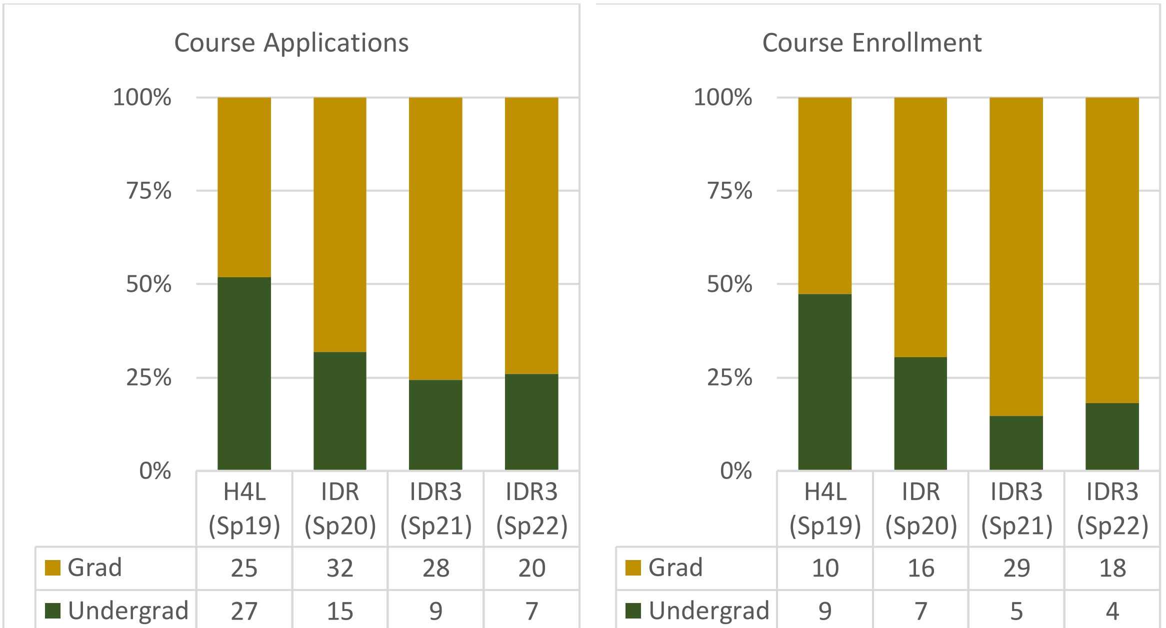


Figure 8: Breakdown of Course Applicants and Enrolled Students – by Class Standing

4.2 Students' Motivations to Enroll in Social-Impact-Driven, Project-Based Elective Courses (RQ-1)

4.2.1 Results: Students' Motivations to Enroll in Social-Impact-Driven, Project-Based Elective Courses (RQ-1)

Students' self-reported motivations for joining the class provided—this information was provided on the course application before the start of the semester—are listed in the following table, from most frequently to least frequently reported.

Table 18: Frequency of Codes Applied to Students' Motivations, DS-1 (n=70 students)

RANK	CODE	THEME	Frequency
1	Change outcome	Theme 4	(n=41)
2	Problem-specific knowledge and skills	Theme 3	(n=25)
3	Product/project outcome	Theme 4	(n=23)
4	Design Thinking/Human-Centered Design	Theme 3	(n=22)
5	Teamwork/interpersonal skills	Theme 2	(n=18)
6	Professional outcome	Theme 4	(n=13)
7	Discipline-specific knowledge and skills	Theme 1	(n=9)

	Ideation and solution development	Theme 3	
8	Type of work/project	Theme 5	(n=8)
9	Course technology specific knowledge and skill sets	Theme 1	(n=6)
10	Client engagement/relationship skills	Theme 2	(n=5)
11	Research, interviewing, and data collection Systems Thinking	Theme 3 Theme 3	(n=4)
12	Prototyping and experimentation	Theme 3	(n=3)
13	Communication skills Project mangement/ leadership skills Frame and reframe promblems Type of organization/team Professional values	Theme 2 Theme 2 Theme 3 Theme 5 Theme 5	(n=1)
14	Academic outcome	Theme 4	(n=2)
15	Time management skills Type of role	Theme 2 Theme 5	(n=0)

4.2.1.1 Student Motivations – by Gender

To identify possible differences in male and female students' motivations for taking the course, the following chart shows the frequency with which each code was applied relative to the number of students in the specific student population. Statistically significant differences (indicated by an asterisk in the chart below) are evaluated in Section 4.2.2.

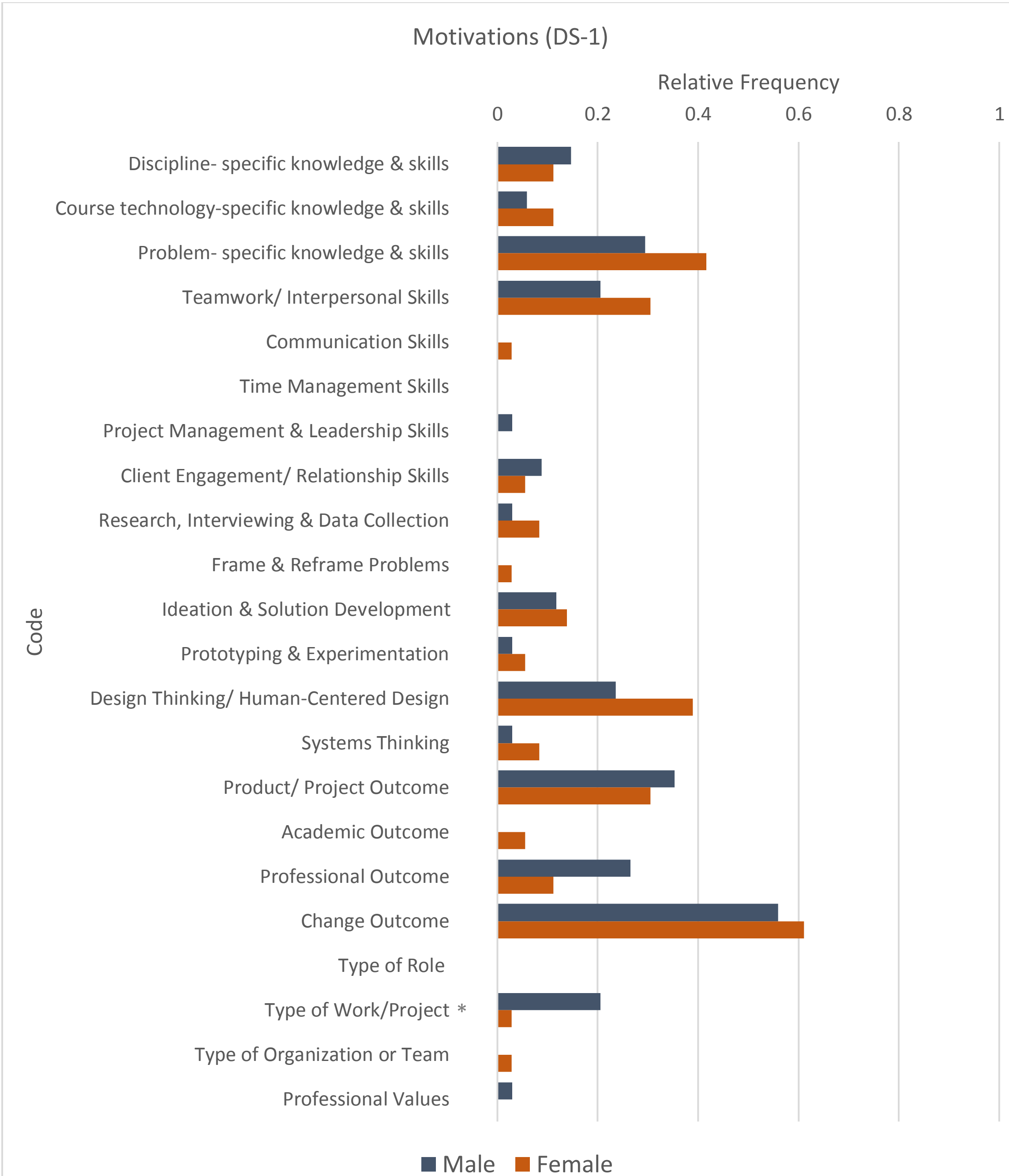


Figure 9: Student Motivations (DS-1) - by Gender

The table that follows compares the most and least frequently applied codes to male and female students' motivations for taking the course.

Table 19: Most/Least Commonly Applied Codes to Student Motivations – by Gender

	STUDENT MOTIVATIONS (DS-1)			
	Male		Female	
3 Most Frequently Applied Codes	Change outcome – Th 4	(n=19)	Change outcome – Th 4	(n=22)
	Product/project outcome – Th 4	(n=12)	Problem-specific knowedge and skills – Th 1	(n=15)
	Problem-specific knowedge and skills – Th 1	(n=10)	Design Thinking/Human-Centered Design – Th 3	(n=14)
3 Least Frequently Applied Coded	Course technology-specific knowledge & skills – Th 1	(n=2)	Client engagement/ relationship Skills – Th 2 Prototyping and Experimentation – Th 3 Academic outcome – Th 5	(n=2)
	Project mangement/ leadership skills – Th 2 Research, interviewing, and data collection – Th 3 Prototyping and Experimentation – Th 3 Systems Thinking – Th 3 Professional Values – Th 5	(n=1)	Communciation skills – Th 2 Frame and reframe problems – Th 3 Type of work/project – Th 5 Type of organization/team – Th 5	(n=1)
	Communciation skills – Th 2 Time management skills – Th 2 Frame and reframe problems – Th 3 Academic Outcome – Th 5 Type of role – Th 5 Type of organization/team – Th 5	(n=0)	Time management skills – Th 2 Project mangement/ leadership skills – Th 2 Type of role – Th 5 Professional values – Th 5	(n=0)

4.2.1.2 Student Motivations – by Discipline

To identify possible differences in engineering and non-engineering students' motivations for taking the course, the following chart shows the frequency with which each code was applied relative to the number of students in the specific student population.

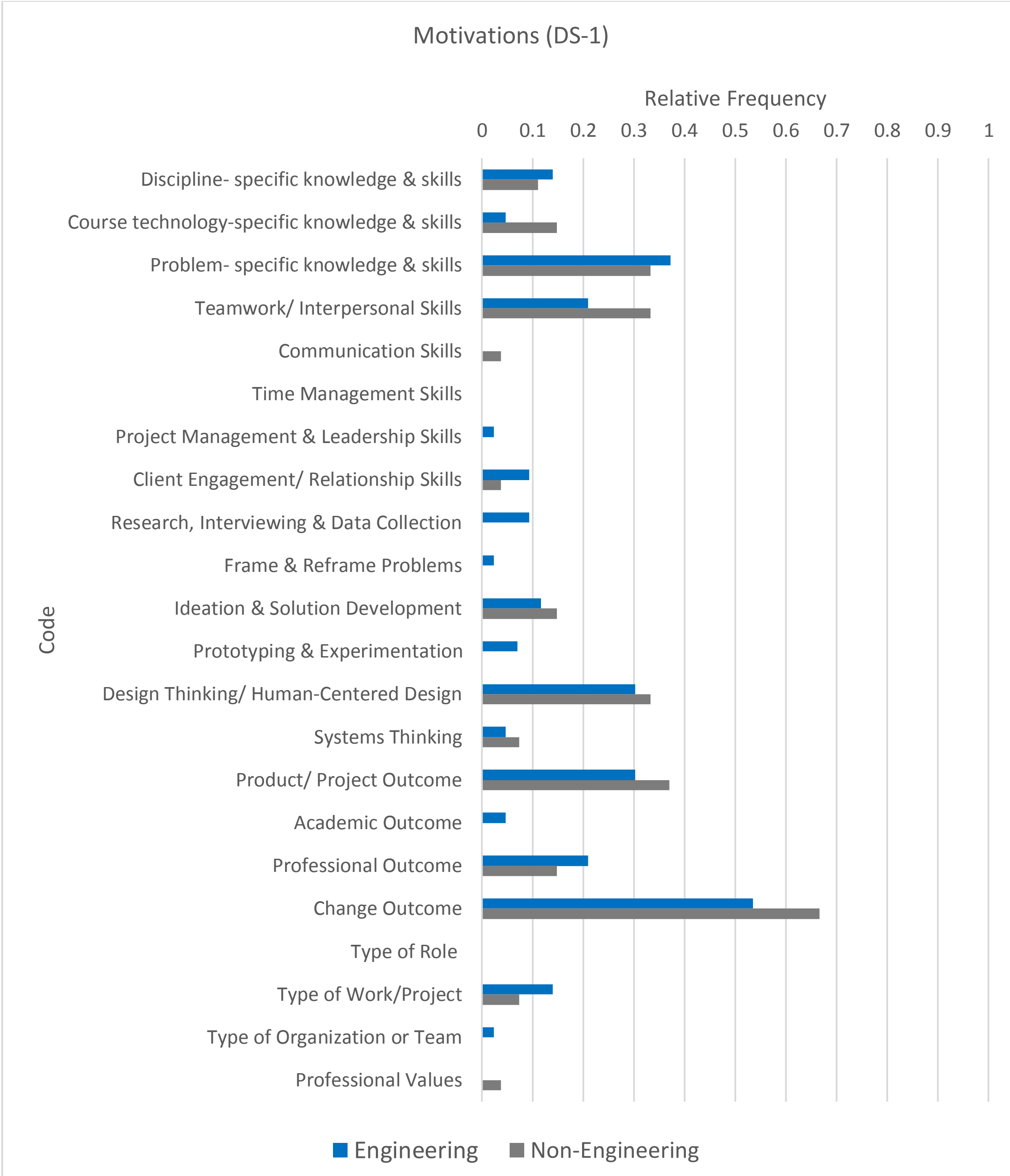


Figure 10: Student Motivations (DS-1) -by Discipline

The table below compares the most and least frequently applied codes to engineering and non-engineering students' motivations for taking the course.

Table 20: Most/Least Commonly Applied Codes to Student Motivations – by Discipline

	STUDENT MOTIVATIONS (DS-1)			
	Engineering		Non-Engineering	
3 Most Frequently Applied Codes	Change outcome – Th 4	(n=23)	Change outcome – Th 4	(n=28)
	Problem-specific knowedge and skills – Th 1	(n=16)	Product/project outcome – Th 4	(n=10)
	Design Thinking/Human-Centered Design – Th 3 Product/project outcome – Th 4	(n=13)	Problem-specific knowedge and skills – Th 1 Teamwork/Interdisciplinary Skills – Th 2 Design Thinking/Human-Centered Design – Th 3	(n=9)
3 Least Frequently Applied Coded	Course technology-specific knowledge & skills – Th 1 Systems thinking – Th 3 Academic outcome – Th 5	(n=2)	Systems thinking – Th 3 Type of work/project – Th 5	(n=2)
	Project mangement/ leadership skills – Th 2 Frame and reframe problems – Th 3 Type of organization/team – Th 5	(n=1)	Communciation skills – Th 2 Client engagement/ relationship Skills – Th 2 Professional Values – Th 5	(n=1)
	Communciation skills– Th 2 Time management skills – Th 2 Type of role – Th 5 Professional values – Th 5	(n=0)	Time management skills – Th 2 Project mangement/ leadership skills – Th 2 Research, Interviewing, and Data Collection – Th 2 Frame and reframe problems – Th 3 Prototyping and Experimentation – Th 3 Academic outcome—Th 5 Type of role – Th 5 Type of organization/team – Th 5	(n=0)

4.2.1.3 Student Motivations – by Class Standing

To identify possible differences in graduate and undergraduate students' motivations for taking the course, the frequency with which each code was applied relative to the number of students in the specific student population. The following chart shows this data. Statistically significant differences (indicated by an asterisk in the chart below) are evaluated in Section 4.2.2.

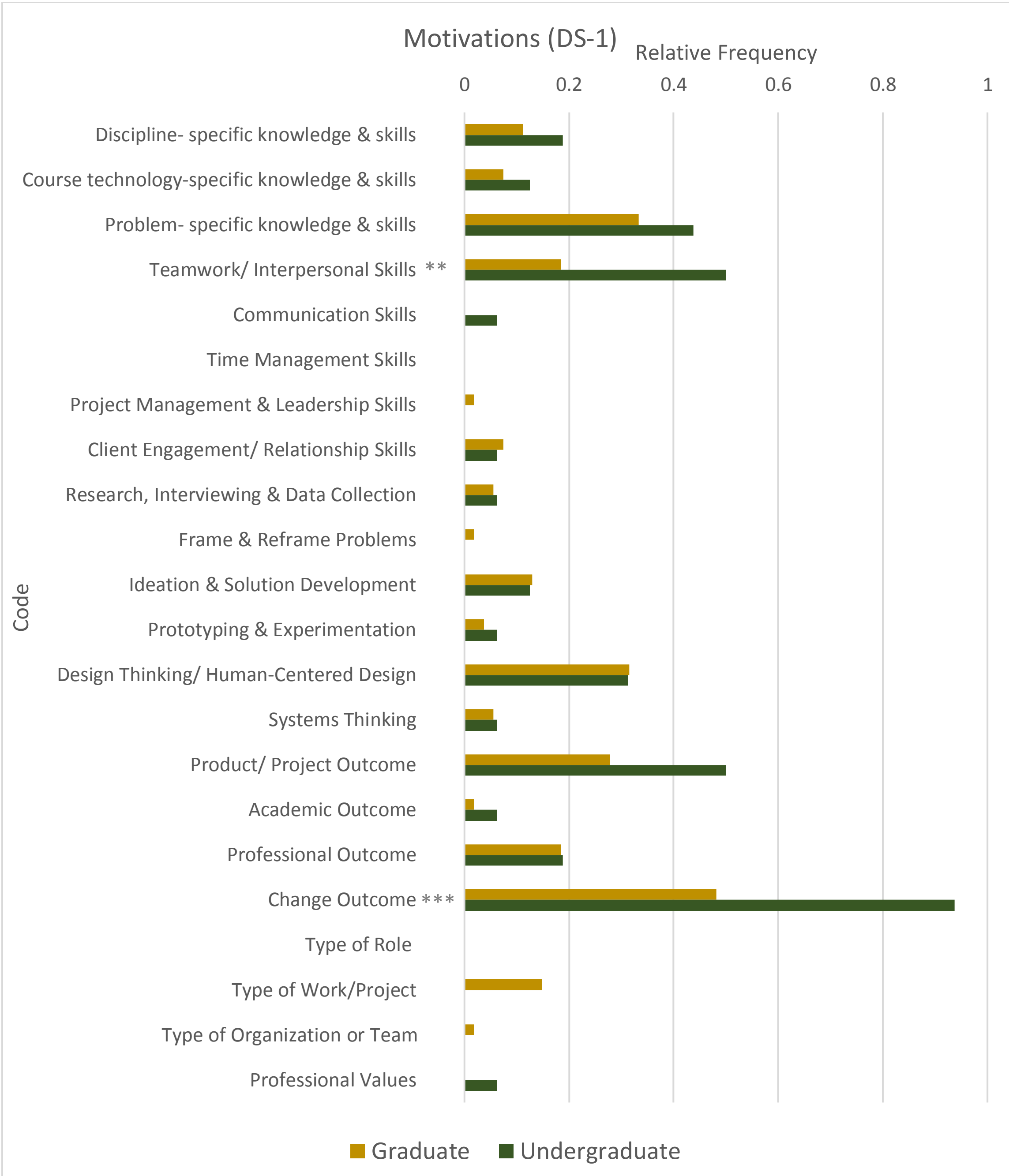


Figure 11: Student Motivations (DS-1) - by Class Standing

The table below compares the most and least frequently applied codes to graduate and undergraduate students' motivations for taking the course.

Table 21: Most/Least Commonly Applied Codes to Student Motivations – by Class Standing

	STUDENT MOTIVATIONS (DS-1)			
	Graduate		**Undergraduate**	
3 Most Frequently Applied Codes	Change outcome – Th 4	(n=26)	Change outcome – Th 4	(n=15)
	Problem-specific knowedge and skills – Th 1	(n=18)	Teamwork/interdisciplinary Skills – Th 2 Product/project outcome – Th 4	(n=8)
	Design Thinking/Human-Centered Design – Th 3	(n=17)	Problem-specific knowedge and skills – Th 1	(n=7)
3 Least Frequently Applied Coded	Prototyping and experimentation – Th 3	(n=2)	Course technology-specific knowledge and skills – Th 1 Ideation and solution development	(n=2)
	Project mangement/ leadership skills – Th 2 Frame and reframe problems – Th 3 Academic outcome – Th 5 Type of organization/ team – Th 5	(n=1)	Communciation skills – Th 2 Client engagement/ relationship skills – Th 2 Research,iInterviewing, and data collection – Th 2 Prototyping and experimentation – Th 3 Systems Thinking – Th 3 Academic outcome – Th 5 Professional values – Th 5	(n=1)
	Communciation skills – Th 2 Time management skills – Th 2 Type of role – Th 5 Professional values – Th 5	(n=0)	Time management skills – Th 2 Project mangement/leadership skills – Th 2 Frame and reframe problems – Th 3 Type of role – Th 5 Type of work/project – Th 5 Type of organization/team – Th 5	(n=0)

4.2.2 Discussion: Students' Motivations to Enroll in Social-Impact-Driven, Project-Based Elective Courses (RQ-1)

Based on the frequency with which each code was applied to students' self-reported motivation provided in the course application, the following table presents the prevalence of each theme from most prevalent to least prevalent in the following table. Considering that each theme had varying numbers of subcodes (ranging from three to six subcodes per theme), the comparison analyzes the average frequency of applied codes based on the number of codes in the given theme.

Table 22: Prevalence of Themes, Student Motivations (DS-1) (N=70 students)

Theme Prevalence	Theme	Frequency	Average Frequency
1. Most Prevalent	Theme 4: Achieve impact-oriented outcome	79	19.8
↕	Theme 1: Develop/apply technical skill sets and discipline-specific knowledge	40	13.3
	Theme 3: Develop/apply design skills/ processes	43	7.2
	Theme 2: Develop/apply professional skill sets	25	5.0
5. Least Prevalent	Theme 5: Journey for career clarity	10	2.5

Students were most motivated by the desire to achieve an impact-oriented outcome (Theme 4) and the desire to develop/apply technical skill sets and content knowledge (Theme 1). The prevalence of themes in students' motivations for each student population (gender, discipline, and class standing) was compared to identify any potential differences in students' motivations between student populations. The prevalence of themes for each student population remained the same (Theme 4, Theme 1, Theme 3, Theme 2, Theme 5; most prevalent to least prevalent).

Overall, 72.9% of students (79.4% of male students, 66.7% of female students; 74.4% of engineering students, 70.4% of non-engineering students; 64.8% of graduate students, and 100% of undergraduate students) indicated at least one motivation related to the most prevalent theme, Theme 4: Achieve an impact-oriented outcome. In contrast, the percentage of students who indicated at least one motivation related to the least prevalent theme, Theme 5: Journey for career clarity, was 12.9% (23.5% of male students, 2.8% of female students; 14.0% of engineering students, 11.1% of non-engineering students; 14.8% of graduate students, and 6.3% of undergraduate students). The percentage of students' motivations coded with at least one code from each theme is shown in the following table. Statistically significant differences in the Themes present in students' motivations are indicated by an asterisk.

Table 23: Student Motivations (DS-1) - by Theme

Theme	ALL (N=70)	GENDER		DISCIPLINE		CLASS STANDING	
		Male (n=34)	Female (n=36)	Eng. (n=43)	Non-Eng. (n=27)	Grad. (n=54)	Under-grad. (n=16)
Theme 1: Develop/apply technical skill sets and discipline-specific knowledge	47.1%	41.2%	52.8%	46.5%	48.1%	44.4%	56.3%
Theme 2: Develop/apply professional skill sets	28.6%	23.5%	33.3%	25.6%	33.3%	22.2%*	50.0%*
Theme 3: Develop/apply design skills /processes	42.9%	32.4%	52.8%	44.2%	40.7%	46.3%	31.3%
Theme 4: Achieve impact-oriented outcome	72.9%	79.4%	66.7%	74.4%	70.4%	64.8%**	100%**
Theme 5: Journey for career clarity	12.9%	23.5%**	2.8%**	14.0%	11.1%	14.8%	6.3%

The frequency of the three most common student motivations and the percentage of student indicating each code are shown in the following table. Students were most motivated by working on large-scale meaningful problems, such as climate change. Students also commonly cited more general altruistic motives such as "creat[ing] something that can save human lives" and "do[ing] something good."

Table 24: Most Frequently Applied Codes to Student Motivations (DS-1) (N=70 students)

Rank	Code	Frequency	Percentage of Students
1	Change outcome – Theme 4: Achieve impact-oriented outcome	41	58.6%
2	Problem-specific knowedge and skills – Theme 1: Technical skill sets and discipline-specific knowledge	25	35.7%
3	Product/project outcome – Theme 4: Achieve impact-oriented	23	32.9%

Achieving a change outcome was the most common motivation coded in students' course applications. Across all three iterations of the course, 58.6% of students (55.8% of male students, 61.1% of female students; 53.5% of engineering students, 66.7% of non-engineering students; 48.2% of graduate students, 93.8% of undergraduate students) cited the desire to achieve a change outcome as a motivation for taking the course.

Applying/developing knowledge and skills specific to the problem space, or the field of disaster response, recovery, and resilience more generally, was the second most common motivation coded in students' course applications. Across all three iterations of the course, 35.7% of students (29.4% of male students, 41.7% of female students; 37.2% of engineering students, 33.3% of non-engineering students; 33.3% of graduate students, 43.8% of undergraduate students), indicated the desire to apply/develop problem-specific knowledge and skills as a motivation for taking the course.

Achieving product/project outcome (e.g., developing a prototype for their portfolio) was the third most common motivation coded in students' course applications. Across all three iterations of the course, 32.9% of students (35.3% of male students, 30.6% of female students; 30.2% of engineering students, 37.0% of non-engineering students; 27.8% of graduate students, 50.0% of undergraduate students), indicated the desire to achieve a product/project outcome as a motivation for taking the course.

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, $X^2(1, N = 70) = 5.48, p < .05$
- Male students were more likely than female students to indicate gaining career clarity (theme 5) as a motivation to join the class, $X^2(1, N = 70) = 6.72, p < .05$

<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, $X^2(1, N = 70) = 6.40, p < .05$

- Undergraduate students were more likely than graduate students to indicate the desire achieve a change outcome as a motivation to join the class, $X^2(1, N = 70) = 10.48, p < .05$

- 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, $X^2(1, N = 70) = 4.67, p < .05$

- 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, $\mathrm{X}^2(1, N = 70) = 7.73\ , p < .05$

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 (report by 58.6% of all students), highlighting the social-impact aspect of course project may increase student enrollment and engagement, across all subpopulations.

4.3 Students' Goals set When Working on Social-Impact-Driven, Project-Based Design Projects (RQ-2)

4.3.1 Results: Students' Goals set When Working on Social-Impact-Driven, Project-Based Design Projects (RQ-2)

Students' self-reported goals for the semester and project provided on the goals survey (DS-2) at the beginning of the semester are listed in the following table, from most frequently to least frequently reported.

Table 25: Frequency of Codes Applied to Student Goals, DS-2 (N=63 students)

RANK	CODE	THEME	Frequency
1	Product/project outcome	Theme 4	(n=33)
2	Teamwork/interpersonal skills	Theme 2	(n=30)
3	Problem-specific knowledge and skills	Theme 3	(n=25)
4	Design Thinking/Human-Centered Design	Theme 3	(n=19)
5	Client engagement/relationship skills Professional outcome	Theme 2 Theme 4	(n=13)
6	Communication skills Change outcome	Theme 2 Theme 4	(n=12)
7	Project management/ leadership skills Research, interviewing, and data collection Ideation and solution development Prototyping and experimentation	Theme 2 Theme 3 Theme 3 Theme 3	(n=8)
8	Discipline-specific knowledge and skill sets	Theme 1	(n=7)
9	Academic outcome	Theme 4	(n=6)
10	Frame and reframe problems Type of work/project	Theme 3 Theme 5	(n=4)
11	Systems Thinking	Theme 4	(n=3)
12	Course technology-specific knowledge and skill sets	Theme 1	(n=2)
13	Time management skills	Theme 2	(n=1)
14	Type of role Type of organization/team Professional values	Theme 5 Theme 5 Theme 5	(n=0)

4.3.1.1 Student Goals – by Gender

To identify possible differences in the goals that male and female students' set for the semester and project, the following chart shows the frequency with which each code was applied relative to the number of students in the specific student population.

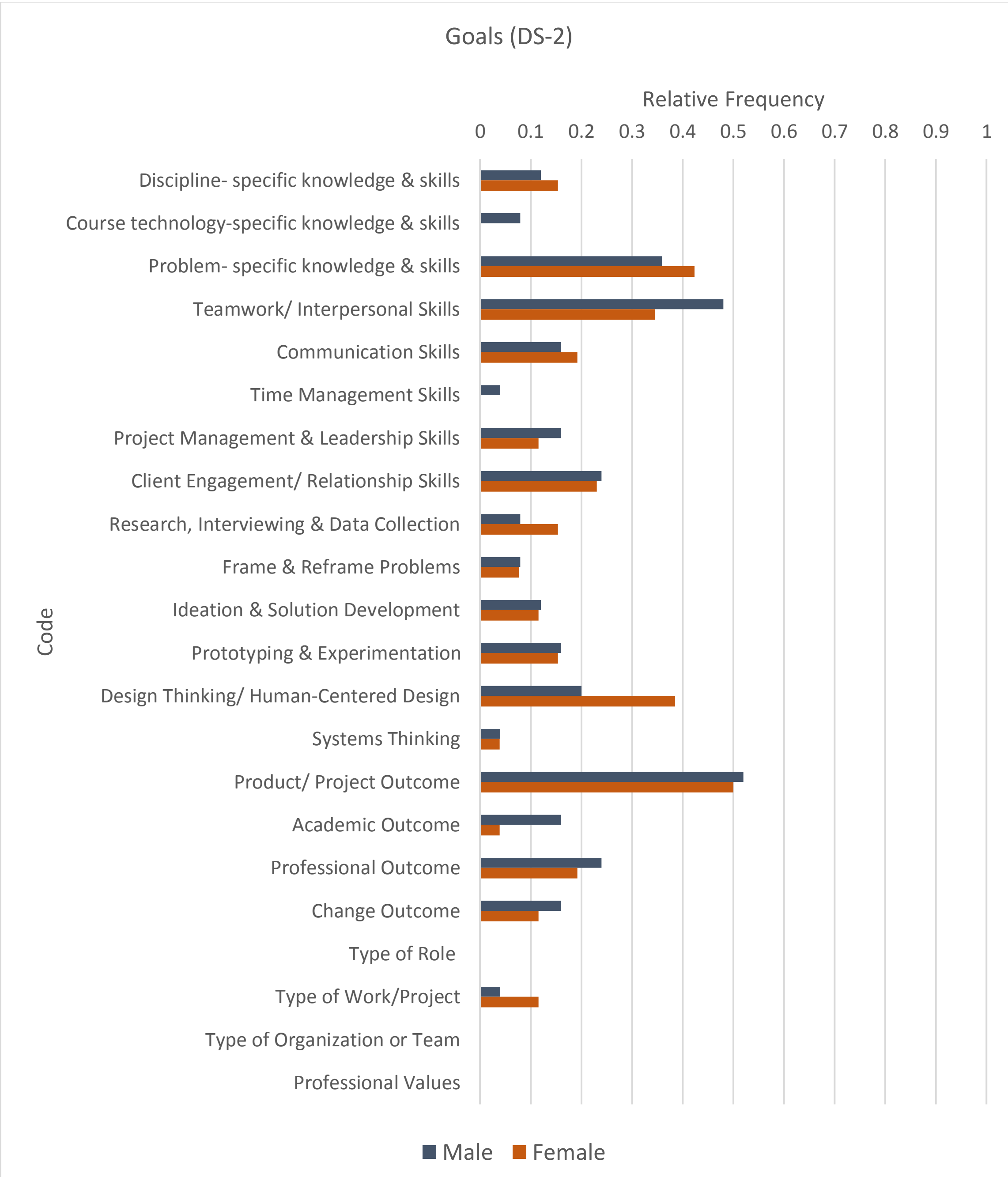


Figure 12: Student Goals (DS-2) - by Gender

The following table compares the most and least frequently applied codes to goals set for the semester and project by male and female students.

Table 26: Most/Least Commonly Applied Codes to Student Goals – by Gender

	STUDENT GOALS (DS-2)			
	Male		Female	
3 Most Frequently Applied Codes	Product/project outcome – Th 4	(n=13)	Product/project outcome – Th 4	(n=13)
	Teamwork/interpersonal skills – Th 2	(n=12)	Problem-specific knowedge and skills – Th 1	(n=11)
	Problem-specific knowedge and skills – Th 1	(n=9)	Design Thinking/Human-Centered Design – Th 3	(n=10)
3 Least Frequently Applied Coded	Course technology-specific knowledge & skills – Th 1 Research, interviewing, and data collection – Th 3 Frame and reframe problems – Th 3	(n=2)	Frame and reframe problems – Th 3	(n=2)
	Time management skills – Th 2 Systems Thinking – Th 3 Type of work/project – Th 5	(n=1)	Systems Thinking – Th 3 Academic outcome – Th 5	(n=1)
	Type of role – Th 5 Type of organization/team – Th 5 Professional values – Th 5	(n=0)	Course technology-specific knowledge & skills – Th 1 Time management skills – Th 2 Type of role – Th 5 Type of organization/team – Th 5 Professional values – Th 5	(n=0)

4.3.1.2 <u>Student Goals – by Discipline</u>

To identify possible differences in the goals that engineering and non-engineering students' set for the semester and project, the frequency with which each code was applied relative to the number of students in the specific student population. The following chart shows this data. Differences determined to be statistically significant are indicated with an asterisk.

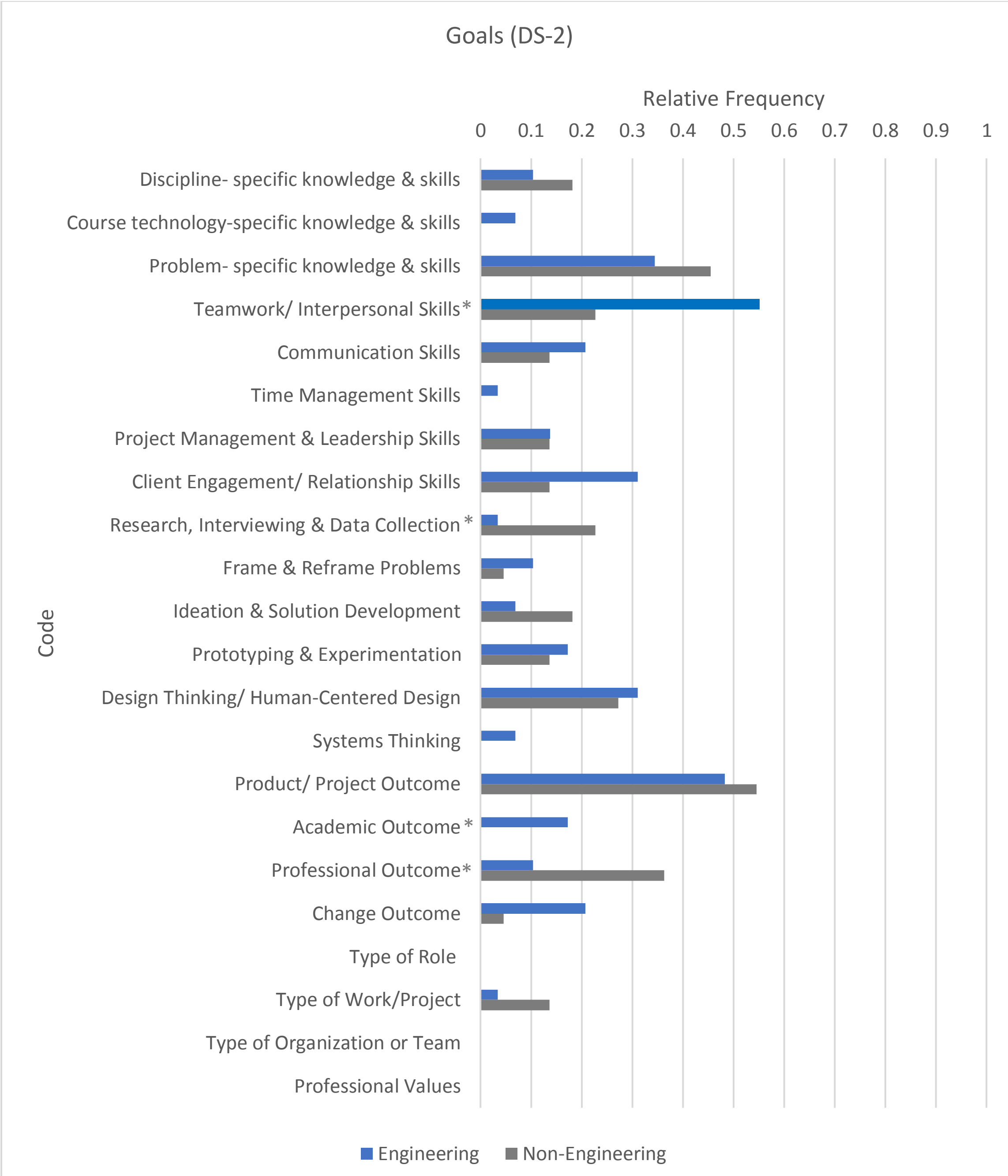


Figure 13: Student Goals (DS-2) - by Discipline

The following table compares the most and least frequently applied codes to goals set for the semester and project by engineering and non-engineering students.

Table 27: Most/Least Commonly Applied Codes to Student Goals – by Discipline

	STUDENT GOALS (DS-2)			
	Engineering		Non-Engineering	
3 Most Frequently Applied Codes	Teamwork/interpersonal skills – Th 2	(n=16)	Product/project outcome – Th 4	(n=12)
	Product/project outcome – Th 4	(n=14)	Problem-specific knowledge and skills – Th 1	(n=10)
	Problem-specific knowledge and skills – Th 1	(n=10)	Professional outcome – Th 4	(n=8)
3 Least Frequently Applied Coded	Course technology-specific knowledge & skills – Th 1 Ideation and solution development – Th 3 Systems Thinking – Th 3	(n=2)	Communication skills – Th 2 Project management/ leadership skills – Th 2 Client engagement/ relationship skills Prototyping and experimentation – Th 3 Type of work/project – Th 5	(n=3)
	Time management skills – Th 2 Research, interviewing, and data collection – Th 3 Type of work/project – Th 5	(n=1)	Frame and reframe problems – Th 3 Change outcome – Th 4	(n=1)
	Type of role – Th 5 Type of organization/team – Th 5 Professional values – Th 5	(n=0)	Course technology-specific knowledge & skills – Th 1 Time management skills – Th 2 Systems Thinking – Th 3 Academic outcome – Th 5 Type of role – Th 5 Type of organization/team – Th 5 Professional values – Th 5	(n=0)

4.3.1.3 Student Goals – by Class Standing

To identify possible differences in the goals that graduate and undergraduate students' set for the semester and project, the frequency each code was applied relative to the number of students in the specific student population. The following chart shows this data.

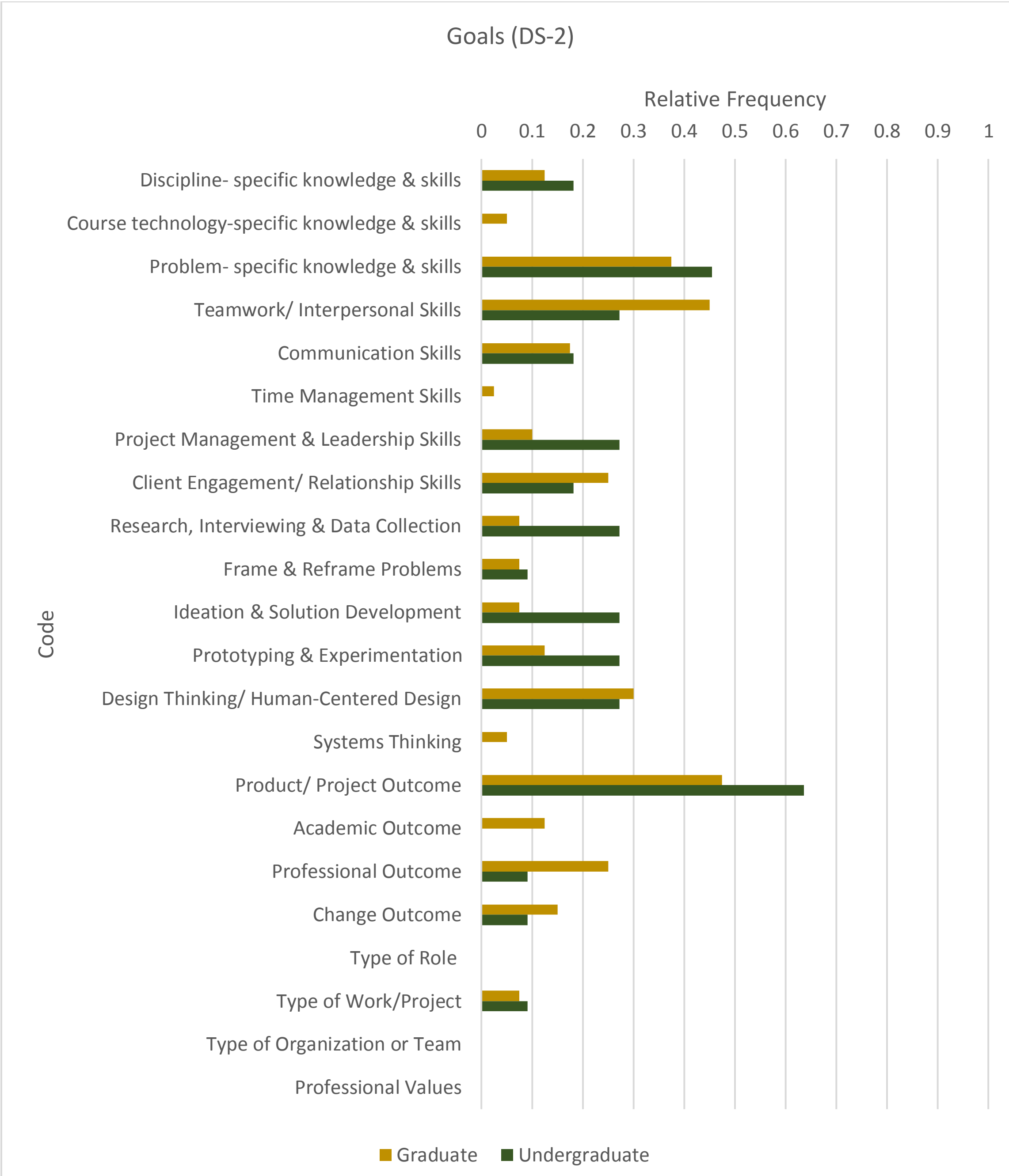


Figure 14: Student Goals (DS-2) - by Class Standing

The table below compares the most and least frequently applied codes to goals set for the semester and project by graduate and undergraduate students.

Table 28: Most/Least Commonly Applied Codes to Student Goals – by Class Standing

	STUDENT GOALS (DS-2)			
	Graduate		Undergraduate	
3 Most Frequently Applied Codes	Product/project outcome – Th 4	(n=19)	Product/project outcome – Th 4	(n=7)
	Teamwork/interpersonal skills – Th 2	(n=18)	Problem-specific knowledge and skills – Th 1	(n=5)
	Problem-specific knowledge and skills – Th 1	(n=15)	Teamwork/interpersonal skills – Th 2 Project management/leadership skills – Th 2 Research, interviewing, and data collection – Th 3 Ideation and solution development – Th 3 Prototyping and experimentation – Th 3 Design Thinking/Human-Centered Design – Th 3	(n=3)
3 Least Frequently Applied Coded	Course technology-specific knowledge & skills – Th 1 Systems Thinking – Th 3	(n=2)	Discipline specific knowledge and skills – Th 1 Communication skills – Th 2 Client engagement/relationship skills – Th 2	(n=2)
	Time management skills – Th 2	(n=1)	Frame and reframe problems – Th 3 Professional outcome – Th 4 Change outcome – Th 4 Type of work/project – Th 5	(n=1)
	Type of role – Th 5 Type of organization/ team – Th 5 Professional values – Th 5	(n=0)	Course technology-specific knowledge & skills – Th 1 Time management skills – Th 2 Systems Thinking – Th 3 Academic outcome – Th 5 Type of role – Th 5 Type of organization/team – Th 5 Professional values – Th 5	(n=0)

4.3.2 Discussion: Students' Goals set When Working on Social-Impact-Driven, Project-Based Design Projects (RQ-2)

Based on the frequency with which each code was applied to students' self-reported goals provided at the beginning of the semester, the prevalence of each theme is shown from most prevalent to least prevalent in the following table. Considering that each theme had varying numbers of subcodes (ranging from three to six codes per theme), the comparison analyzes the average frequency of applied codes based on the number of codes in the given theme.

Table 29: Prevalence of Themes, Student Goals (DS-2) (N=63 students)

Theme Prevalence	Theme	Frequency	Average Frequency
1. Most Prevalent	Theme 4: Achieve impact-oriented outcome	64	16.0
↑	Theme 2: Develop/apply professional skill sets	64	12.8
	Theme 1: Technical skill sets and discipline-specific Knowledge	34	11.3
↓	Theme 3: Develop/apply design skills/ processes	50	8.3
5. Least Prevalent	Theme 5: Journey for career clarity	4	1.0

Students' goals were mostly related to impact-oriented outcomes (Theme 4) and the development/application of professional skill sets (Theme 2). The prevalence of themes in students' goals did vary slightly between student subgroup populations by gender (male and female students), discipline (engineering and non-engineering students), and class standing (graduate and undergraduate students), as shown in the following table.

Table 30: Prevalence of Student Goals (DS-2), by Student Population Groups

Theme Prevalence	ALL	GENDER		DISCIPLINE		CLASS STANDING	
		Male	Female	Engineeri ng	Non-Engineering	Graduate	Under-graduate
1. Most Prevalent	Theme 4	Theme 4	Theme 4	Theme 2	Theme 4	Theme 4	Theme 1
↑	Theme 2	Theme 2	Theme 1	Theme 4	Theme 1	Theme 2	Theme 4
	Theme 1	Theme 1	Theme 2	Theme 1	Theme 3	Theme 1	Theme 3
↓	Theme 3	Theme 3	Theme 3	Theme 3	Theme 2	Theme 3	Theme 2
5. Least Prevalent	Theme 5	Theme 5	Theme 5	Theme 5	Theme 5	Theme 5	Theme 5

Overall, the percentage of students who indicated at least one goal related to the most prevalent theme (Theme 4: Achieve an impact-oriented outcome) was 69.8% (68.0% of male students, 61.5% of female students; 65.5% of engineering students, 63.6% of non-engineering students; 65.0% of graduate students, and 63.6% of undergraduate students). In contrast, the percentage of students who indicated at least one goal related to the least prevalent theme (Theme 5: Journey for career clarity) was 6.3% (4.0% of male students, 11.5% of female students; 3.4% of engineering students, 13.6% of non-engineering students; 7.5% of graduate students, and 9.1% of undergraduate students). The percentage of students' goals coded with at least one code from each theme is shown in the following table.

Table 31: Student Goals (DS-2) - by Theme

Theme	ALL (N=63)	GENDER		DISCIPLINE		CLASS STANDING	
		Male (n=25)	Female (n=26)	Eng. (n=29)	Non-Eng. (n=22)	Grad. (n=40)	Under-grad. (n=11)
Theme 1: Develop/apply technical skill sets and discipline-specific knowledge	49.2%	48.0%	53.8%	44.8%	59.1%	47.5%	63.6%
Theme 2: Develop/apply professional skill sets	71.4%	64.0%	65.4%	75.9%	50.0%	65.0%	63.6%
Theme 3: Develop/apply design skills /processes	49.2%	44.0%	50.0%	44.8%	50.0%	47.5%	45.5%
Theme 4: Achieve impact-oriented outcome	69.8%	68.0%	61.5%	65.5%	63.6%	65.0%	63.6%
Theme 5: Journey for career clarity	6.3%	4.0%	11.5%	3.4%	13.6%	7.5%	9.1%

The frequency of the three most frequently coded students' goals, and percentage of students who indicated the code as a goal, are shown in the following table.

Table 32: Most Frequently Applied Codes to Student Goals (DS-2) (N=63 students)

Rank	Code	Frequency	Percentage of Students
1	Product/project outcome (Theme 4: Achieve impact-oriented outcome)	33	52.4%
2	Teamwork/interpersonal skills (Theme 2: Apply/develop professional skill sets)	30	47.6%
3	Problem-specific knowledge and skills (Theme 1: Apply/develop technical skill sets and content knowledge)	25	40.0%

Achieving product/project outcome (e.g., developing a prototype for their portfolio or developing a solution for their project) was the most common goal coded in students' responses to the goals survey completed at the beginning of the semester after course project and team assignments were announced. Across all three iterations of the course, 52.4% of students (52.0% of male students, 50.0% of female students; 48.3% of engineering students, 54.6% of non-engineering students; 47.5% of graduate students, 63.6% of undergraduate students), indicated the desire to achieve a product/project outcome as a goal for the semester.

Applying/developing teamwork/interpersonal skills was the second most common goal coded in students' responses to the goals survey. Across all three iterations of the course, 47.6% of students (48.0% of male students, 34.7% of female students; 55.2% of engineering students, 22.7% of non-engineering students; 45.0% of graduate students, 27.3% of undergraduate students), indicated the desire to apply/develop teamwork/interpersonal skills as a goal for the semester.

Applying/developing knowledge and skills specific to the problem space, or the field of disaster response, recovery, and resilience more generally, was the third most common goal coded in students' responses to the goals survey. Across all three iterations of the course, 40.0% of students (36.0% of male students, 42.3% of female students; 34.5% of engineering students, 45.5% of non-engineering students; 37.5% of graduate students, 45.5% of undergraduate students), indicated the desire to apply/develop problem-specific knowledge and skills as a goal for the semester.

To further explore differences in students' goals 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:

<u>Discipline</u>

- Engineering students were more likely than non-engineering students to indicate developing/applying teamwork/interpersonal skills as a goal, $\mathrm{X}^2(1, N = 51) = 5.44, p < .05$
- Non-engineering students were more likely than engineering students to indicate conducting research, interviews, and data collection as a goal, $\mathrm{X}^2(1, N = 51) = 4.47, p < .05$
- Engineering students were more likely than non-engineering students to indicate achieving an academic outcome as a goal, $\mathrm{X}^2(1, N = 51) = 4.21, p < .05$
- Non-engineering students were more likely than engineering students to indicate achieving a professional outcome as a goal, $\mathrm{X}^2(1, N = 51\ ) = 5.01, p < .05$

A chi-square test of independence showed there was no significant association between student sub-populations: 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 engineering and non-engineering students' goals were shown in the results of a chi-square test of independence. Mainly, engineering students were more likely than non-engineering students to set goals related to the developing/applying teamwork/interpersonal skills and achieving academic outcomes (such as fulfilling certificate requirements or passing the class). Conversely, non-engineering students were more likely than engineering students to set goals related to developing/applying research, interviewing, and data collection skills, as well as goals related to achieving professional outcomes (such as developing a portfolio product).

One hypothesis for engineering students' increased likelihood of setting goals related to developing teamwork/interpersonal skills could be due to less emphasis on teaming in engineering curriculum overall. Some engineering students' goals indicated the possibility of difficulties with prior team experiences through goal statements like "still like my group at the end of the project." Additionally, many engineering students also indicated the value of working on non-engineers in final reflections, which could also indicate a lack of similar teaming experiences in previous engineering courses.

While engineering students were the only subpopulation to significantly be more likely to set goals related developing teamwork/interpersonal skills, this code was the second most prevalent code for student goals (reported by 47.6% of all students, increased from 25.7% of all students' motivations). As student goals were elicited after students were notified of their project and team assignments, an increase in students' desired outcomes to include teamwork/interpersonal skills could indicate students begin to value such learning opportunities as they gain a better understanding of their engagement with the course. This increase suggests that instructors could benefit from instructional interventions to scaffold the development of teamwork/interpersonal skills with teaming strategies. Additionally, goal congruence, an aligned set of common goals for the team, result in higher team performance and better outcomes (Beckman et al., 2021).

4.4 Students' Perceived Value from Participating in Social-Impact-Driven, Project-Based Design Opportunities (RQ-3)

4.4.1 Results: Students' Perceived Value from Participating in Social-Impact-Driven, Project-Based Design Opportunities (RQ-3)

Students' self-reported perceived value from participating in the course is captured in the final reflections (DS-3) submitted at the conclusion of the semester; the following table shows this information, which is listed from most frequently to least frequently reported.

Table 33: Frequency of Codes Applied to Students' Perceived Value, DS-3 (N=68 students)

RANK	CODE	THEME	Frequency
1	Teamwork/interpersonal skills	Theme 2	(n=48)
2	Research, interviewing, and data collection	Theme 3	(n=41)
3	Frame and reframe problems	Theme 3	(n=37)
4	Type of work	Theme 5	(n=36)
5	Design Thinking/Human-Centered Design	Theme 3	(n=34)
6	Communication skills	Theme 2	(n=25)
7	Ideation and solution development	Theme 3	(n=24)
8	Problem-specific knowledge and skills	Theme 1	(n=23)
9	Prototyping and experimentation	Theme 3	(n=20)
10	Course technology-specific knowledge and skill sets	Theme 1	(n=18)
11	Project management and leadership skills Client engagement/relationship skills	Theme 2 Theme 2	(n=17)
12	Type of organization/team	Theme 5	(n=15)
13	Systems Thinking Change outcome	Theme 3 Theme 4	(n=14)
14	Product/project outcome Professional values	Theme 4 Theme 5	(n=13)
15	Professional outcomes	Theme 4	(n=12)
16	Time management skills	Theme 2	(n=6)

	Type of Role	Theme 5	
17	Discipline-specific knowledge and skill sets	Theme 1	(n=3)
18	Academic outcome	Theme 4	(n=1)

4.4.1.1 Student Perceived Value (End of Course) – by Gender

To identify possible differences in male and female students' perceived value identified at the end of the course, the frequency with which each code was applied relative to the number of students in the specific student population. The following chart illustrates this data. Differences determined to be statistically significant are indicated with an asterisk.

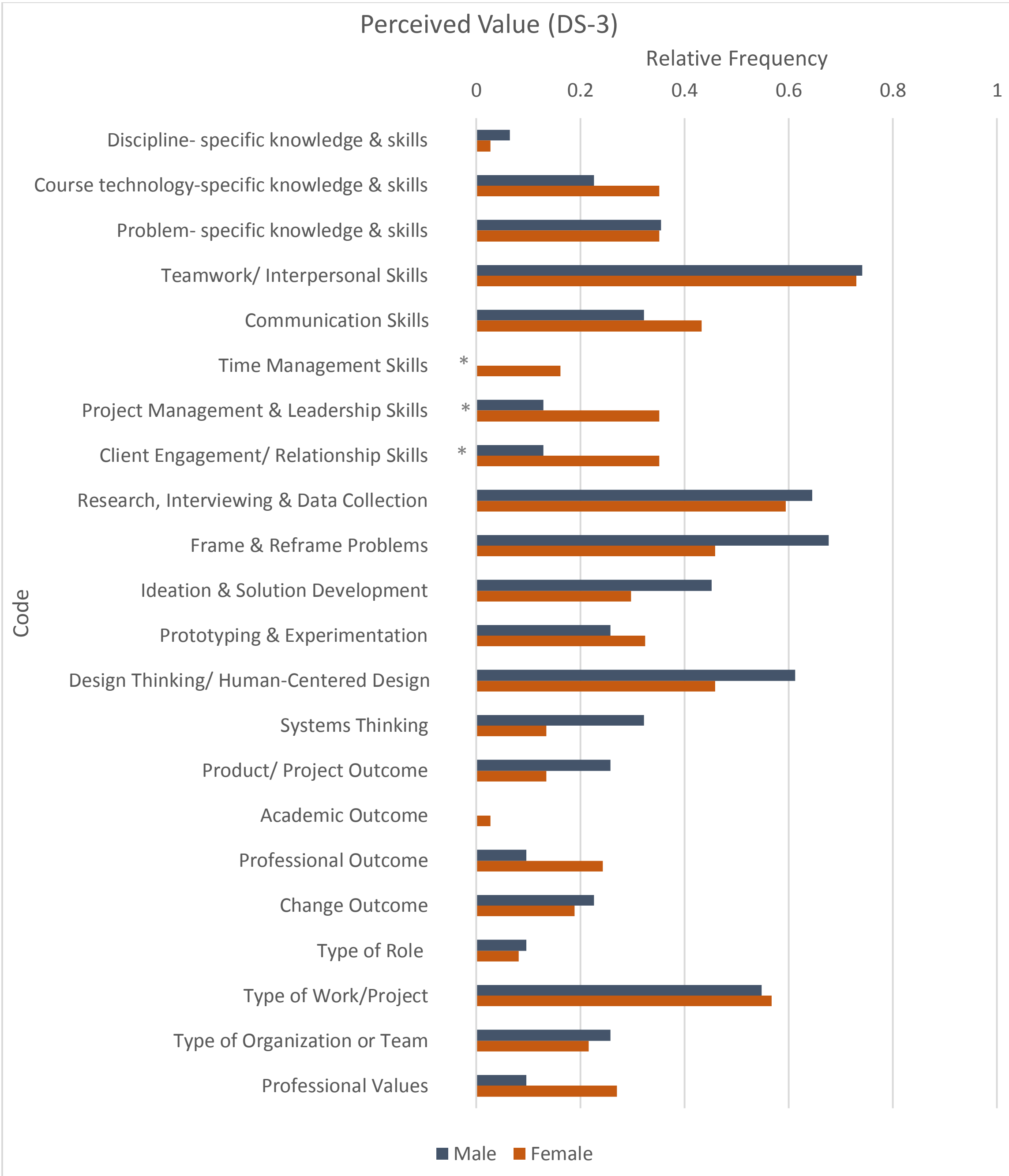


Figure 15: Student Perceived Value (DS-3) - by Gender

The table below compares the most and least frequently applied codes to male and female students' perceived value indicated at the end of the course.

Table 34: Most/Least Commonly Applied Codes to Student Perceived Value – by Gender

	STUDENT PERCEIVED VALUE (DS-3)			
	Male		Female	
3 Most Frequently Applied Codes	Teamwork/interpersonal skills – Th 2	(n=22)	Teamwork/interpersonal skills – Th 2	(n=26)
	Frame and reframe problems – Th 3	(n=20)	Research, interviewing, and data collection – Th 3	(n=22)
	Research, interviewing, and data collection – Th 3	(n=19)	Type of work/project – Th 5	(n=20)
3 Least Frequently Applied Coded	Professional Outcome – Th 4 Professional values – Th 5	(n=3)	Time management skills – Th 2	(n=6)
	Discipline specific knowledge and skills – Th 1	(n=2)	Systems Thinking – Th 3 Product/project outcome – Th 4	(n=5)
	Time management skills – Th 2 Academic outcome – Th 5	(n=0)	Discipline specific knowledge and skills – Th 1 Academic outcome – Th 5	(n=1)

4.4.1.2 Student Perceived Value (End of Course) – by Discipline

To identify possible differences in engineering and non-engineering students' perceived value identified at the end of the course, the frequency with which each code was applied relative to the number of students in the specific student population. The following chart shows this data.

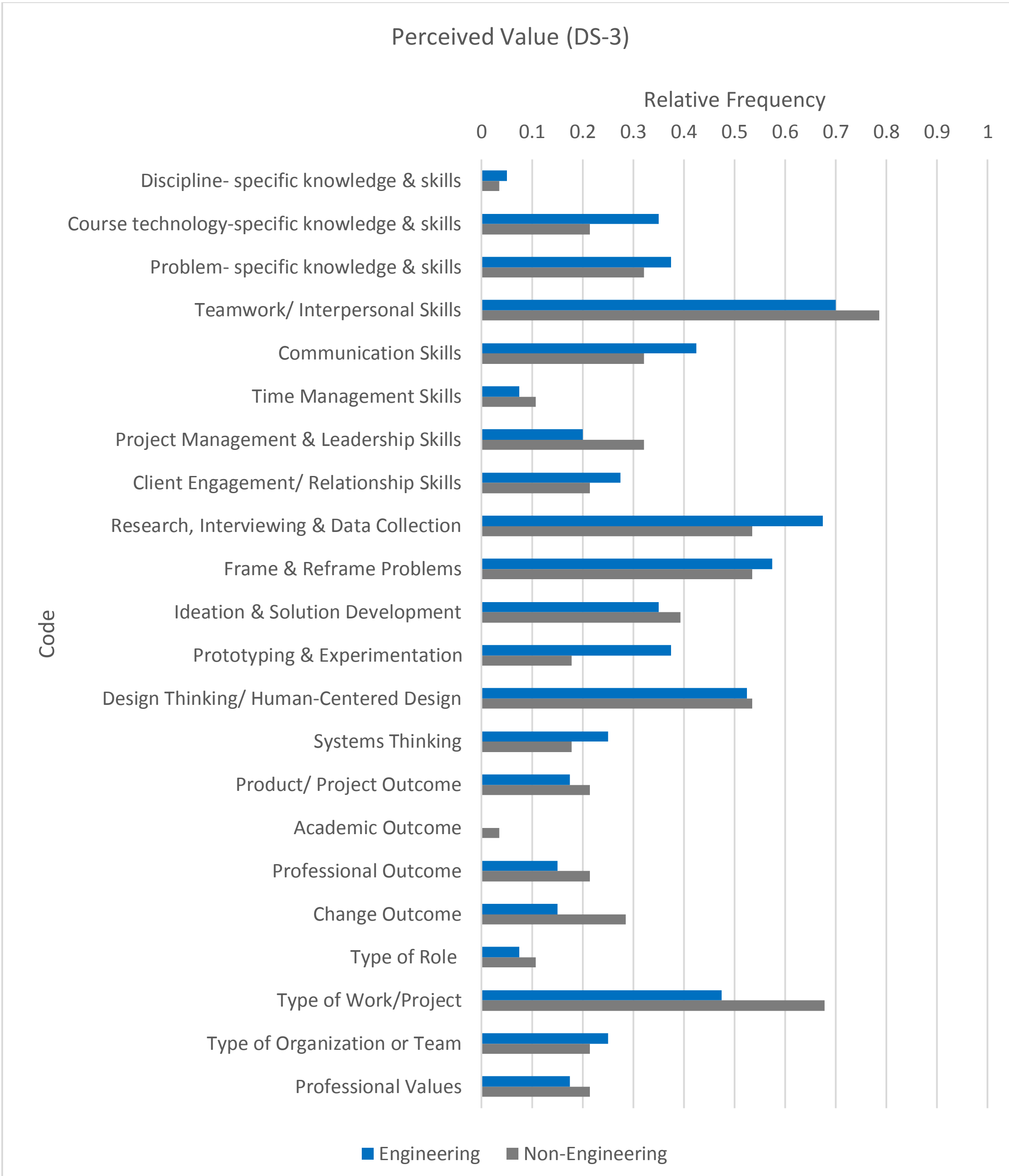


Figure 16: Student Perceived Value (DS-3) - by Discipline

The following table compares the most and least frequently applied codes to engineering and non-engineering students' perceived value indicated at the end of the course.

Table 35: Most/Least Commonly Applied Codes to Student Perceived Value – by Discipline

	STUDENT PERCEIVED VALUE (DS-3)			
	Engineering		Non-Engineering	
3 Most Frequently Applied Codes	Teamwork/interpersonal skills – Th 2	(n=27)	Teamwork/interpersonal skills – Th 2	(n=21)
	Research, interviewing, and data collection – Th 3	(n=26)	Type of work/project – Th 5	(n=18)
	Frame and reframe problems – Th 3	(n=22)	Research, interviewing, and data collection – Th 3 Frame and reframe problems – Th 3	(n=15)
3 Least Frequently Applied Coded	Time management skills – Th 2 Type of role – Th 5	(n=3)	Systems Thinking – Th 3	(n=4)
	Discipline specific knowledge and skills – Th 1	(n=2)	Time management skills – Th 2	(n=3)
	Academic outcome – Th 5	(n=0)	Discipline specific knowledge and skills – Th 1 Academic outcome – Th 5	(n=1)

4.4.1.3 Student Perceived Value (End of Course) – by Class Standing

To identify possible differences in graduate and undergraduate students' perceived value identified at the end of the course, the frequency with which each code was applied relative to the number of students in the specific student population. The following chart shows this data.

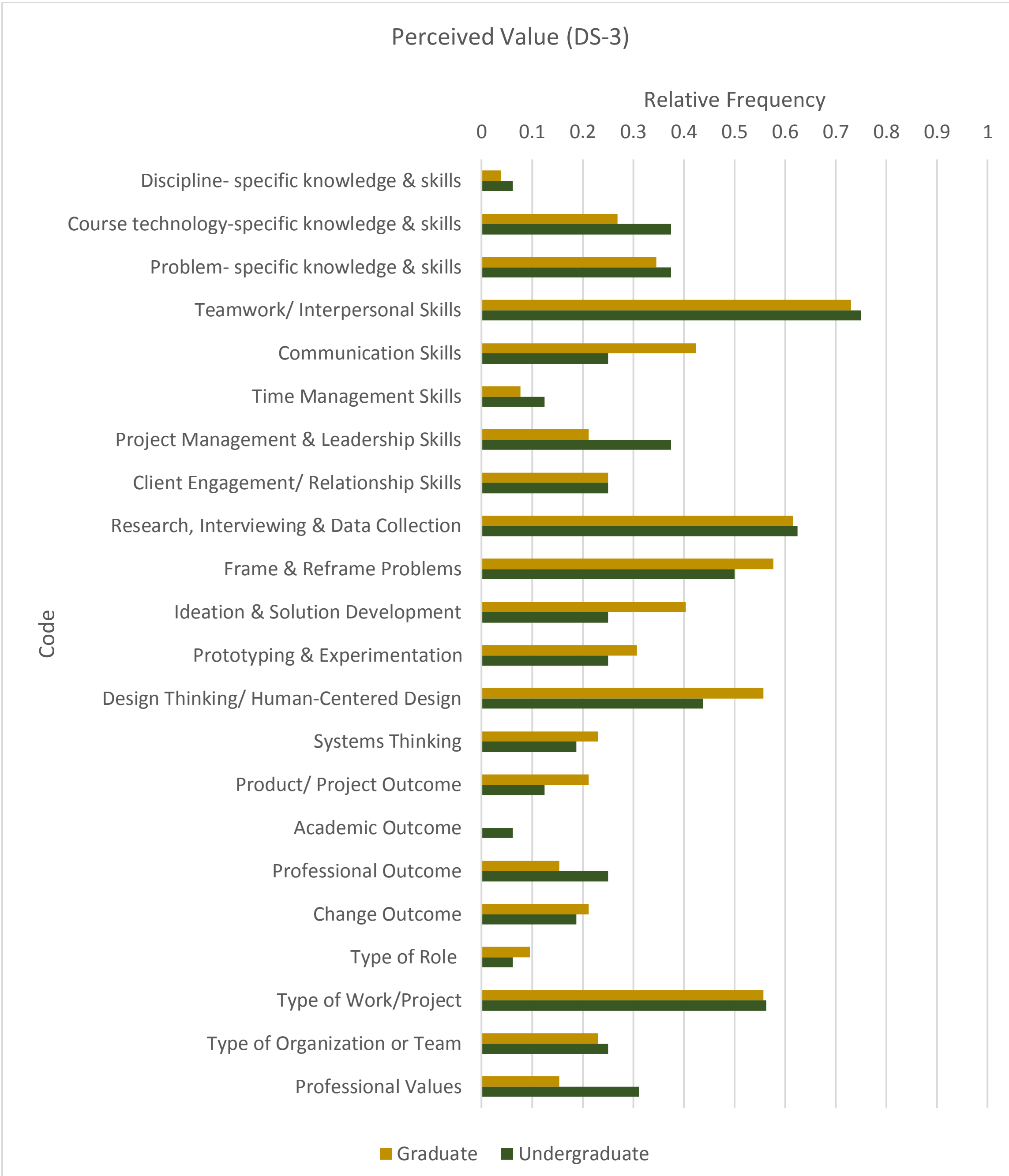


Figure 17: Student Perceived Value (DS-3) - by Class Standing

The following table compares the most and least frequently applied codes to graduate and undergraduate students' perceived value indicated at the end of the course.

Table 36: Most/Least Commonly Applied Codes to Student Perceived Value – by Class Standing

	STUDENT PERCEIIVED VALUE (DS-3)			
	Graduate		Undergraduate	
3 Most Frequently Applied Codes	Teamwork/interpersonal skills – Th 2	(n=37)	Teamwork/interpersonal skills – Th 2	(n=11)
	Research, interviewing, and data collection – Th 3	(n=31)	Research, interviewing, and data collection – Th 3	(n=10)
	Frame and reframe problems – Th 3	(n=29)	Frame and reframe problems – Th 3 Type of work/project – Th 5	(n=8)
3 Least Frequently Applied Coded	Time management skills – Th 2	(n=4)	Change outcome – Th 4	(n=4)
	Discipline specific knowledge and skills – Th 1	(n=2)	Time management skills – Th 2 Systems Thinking – Th 3 Product/project outcome – Th 4	(n=2)
	Academic outcome – Th 5	(n=0)	Discipline specific knowledge and skills – Th 1 Academic outcome – Th 5 Type of role – Th 5	(n=1)

4.4.1.4 Student Perceived Value (Longitudinal)

As students gain experience working in professional environments, students accumulate opportunities to evaluate and assess the value of the skill sets they developed/learned with respect to what skills they need in their professional practice. Post-course interviews were conducted with students to explore how students' perspectives on the perceived value of participation in social-impact-driven, project-based learning opportunities changed as they progress in their professional practice and career. A total of 12 semi-structured interviews, ranging from 30- to 45-minutes in duration, were conducted with students one to three years after completing the Innovation in Disaster Response (Sp20) or Innovation in Disaster Response, Resilience, and Recovery (Sp21, Sp22). Details about the interview protocol are provided in Section 3.4.4. Details about the participants of the post-course interview are provided in the following table.

Table 37: Post-Course Interview (DS-4) Participants

COURSE	GENDER		DISCIPLINE		CLASS STANDING	
	Female	Male	Engineering	Non-Engineering	Graduate	Undergraduate
IDR (Sp20)	3	2	2	3	5	0
IDR3 (Sp21)	2	0	1	1	2	0
IDR3 (Sp22)	3	2	3	2	3	2
ALL	8	4	6	6	10	2

Students' interviews were recorded, transcribed, and coded using the themes and codes described in Section 3.6. The following graph depicts the number of interview responses with each code applied.

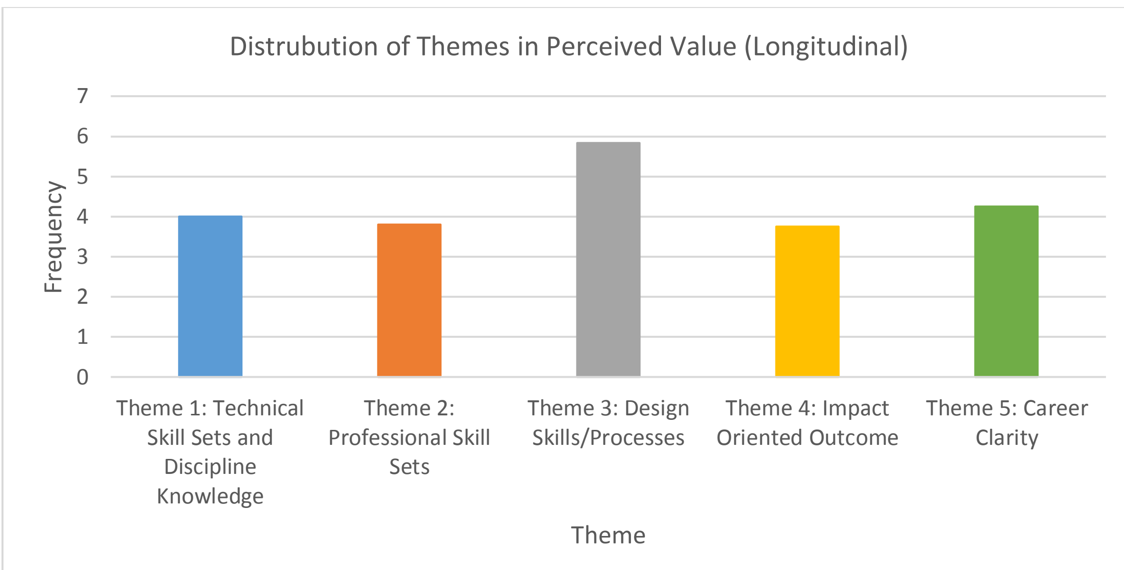


Figure 18: Student Perceived Value – Longitudinal (DS-4) by Theme

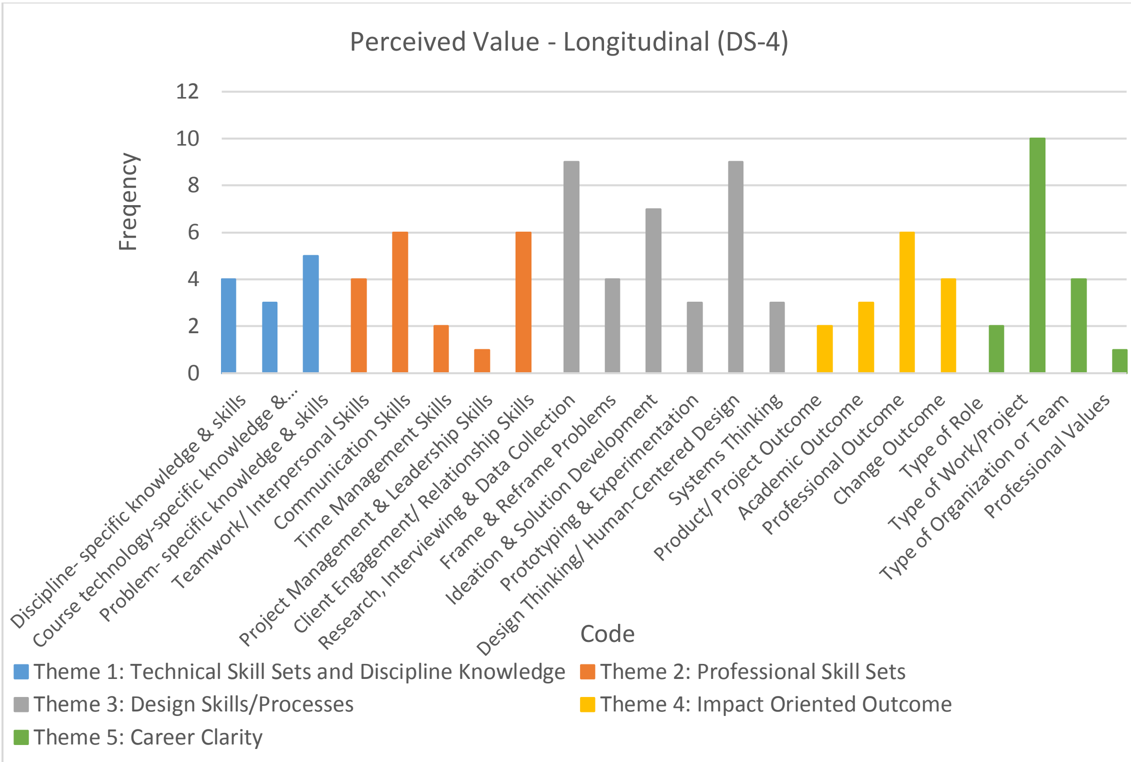


Figure 19: Student Perceived Value - Longitudinal (DS-4)

The following table shows the prevalence of each code applied to students' post-course interview (DS-4) responses; the order is shown from most frequently to least frequently applied.

Table 38: Frequency of Codes Applied to Student Perceived Value - Longitudinal, DS-4 (N=12 interviews)

RANK	CODE	THEME	Frequency
1	Type of work/project	Theme 5	(n=10)
2	Research, interviewing, and data collection Design Thinking/Human-Centered Design	Theme 3 Theme 3	(n=9)
3	Ideation and solution development	Theme 3	(n=7)
4	Communication skills Client engagement/relationship skills Professional outcome	Theme 2 Theme 2 Theme 4	(n=6)
5	Problem-specific knowledge and skills	Theme 1	(n=5)
6	Discipline-specific knowledge and skills Teamwork/interpersonal skills	Theme 1 Theme 2	(n=4)

	Frame and reframe problems Change outcome Type of organization/team	Theme 3 Theme 4 Theme 5	
7	Course technology-specific knowledge and skill sets Prototyping and experimentation Systems Thinking Academic outcome	Theme 1 Theme 3 Theme 3 Theme 4	(n=3)
8	Time management skills Product/project outcome Type of role	Theme 2 Theme 4 Theme 5	(n=2)
9	Project management/ leadership skills Professional values	Theme 2 Theme 5	(n=1)

4.4.2 Discussion: Students' Perceived Value from Participating in Social-Impact-Driven, Project-Based Design Opportunities (RQ-3)

4.4.2.1 Students' Perceived Value – Course Completion

Based on the frequency with which each code was applied to students' self-reported perceived value at the conclusion of the semester, the following table shows the prevalence of each theme from most prevalent to least prevalent. Considering that each theme had varying numbers of subcodes, the comparison analyzes the average frequency of applied codes based on the number of codes in the given theme.

Table 39: Prevalence of Themes, Student Perceived Value (DS-3) (N=68 student reflections)

Theme Prevalence	Theme	Frequency	Average Frequency
1. Most Prevalent ↑	Theme 3: Develop/apply design skills/ processes	170	28.3
	Theme 2: Develop/apply professional skill sets	113	22.6
	Theme 5: Journey for career clarity	70	17.5
	Theme 1: Technical skill sets and discipline-specific knowledge	44	14.7
↓ 5. Least Prevalent	Theme 4: Achieve impact-oriented outcome	40	10.0

Students' perceived values were mostly related to the development/application of design skills/processes (Theme 3) and the development/application of professional skill sets

(Theme 2). The prevalence of themes in students' goals did vary between student subgroup populations by gender (male and female students), discipline (engineering and non-engineering students), and class standing (graduate and undergraduate students), as shown in the following table.

Table 40: Prevalence of Student Perceived Value (DS-3), by Student Population Groups

Theme Prevalence	ALL	GENDER		DISCIPLINE		CLASS STANDING	
		Male	Female	Engineer-ing	Non-Engineering	Graduate	Under-graduate
1. Most Prevalent	Theme 3	Theme 3	Theme 2	Theme 3	Theme 3	Theme 3	Theme 3
↕	Theme 2	Theme 2	Theme 3	Theme 2	Theme 2	Theme 2	Theme 2
	Theme 5	Theme 5	Theme 5	Theme 1	Theme 5	Theme 5	Theme 5
	Theme 1	Theme 1	Theme 1	Theme 5	Theme 4	Theme 1	Theme 1
5. Least Prevalent	Theme 4	Theme 4	Theme 4	Theme 4	Theme 1	Theme 4	Theme 4

Overall, the percentage of students who indicated at least one perceived value related to the most prevalent theme (Theme 3: Develop/apply design skills/processes) was 88.3% (90.3% of male students, 86.5% of female students; 90.0% of engineering students, 85.7% of non-engineering students; 92.3% of graduate students, and 75.0% of undergraduate students). In contrast, the percentage of students who indicated at least one perceived value related to the least prevalent theme (Theme 4: Achieve impact-oriented outcome) was 41.2% (35.5% of male students, 45.9% of female students; 35.0% of engineering students, 50.0% of non-engineering students; 38.5% of graduate students, and 50.0% of undergraduate students). The percentage of students' perceived value responses coded with at least one code from each theme is shown in the following table. Statistically significant differences are indicated with an asterisk.

Table 41: Student Perceived Value (DS-3) - by Theme

Theme	ALL (N=68)	GENDER		DISCIPLINE		CLASS STANDING	
		Male (n=31)	Female (n=37)	Eng. (n=40)	Non-Eng. (n=28)	Grad. (n=52)	Under-grad. (n=16)
Theme 1: Develop/apply technical skill sets and discipline-specific knowledge	50.0%	51.6%	48.6%	55.0%	42.9%	50.0%	50.0%
Theme 2: Develop/apply professional skill sets	85.3%	74.2%*	94.6%*	82.5%	89.3%	84.6%	87.5%
Theme 3: Develop/apply design skills /processes	88.3%	90.3%	86.5%	90.0%	85.7%	92.3%	75.0%
Theme 4: Achieve impact-oriented outcome	41.2%	35.5%	45.9%	35.0%	50.0%	38.5%	50.0%
Theme 5: Journey for career clarity	63.3%	61.3%	64.9%	57.5%	71.4%	63.5%	62.5%

The frequency of the three most frequently coded students' perceived values, and the percentage of student responses coded, are shown in the following table.

Table 42: Most Frequently Applied Codes to Student Perceived Value (DS-3) (N=68 students)

Rank	Code	Frequency	Percentage of Students
1	Teamwork/interpersonal skills (Theme 2: Apply/develop professional skill sets)	48	70.6%
2	Research, interviewing, and data collection (Theme 3: Apply/develop design skills/processes)	41	60.3%
3	Frame and reframe problems (Theme 3: Apply/develop design skills/processes)	37	54.4%

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. Across all three iterations of the course, 70.6% of students (71.0% of male students, 70.3% of female students; 67.5% of engineering students, 75.0% of non-engineering students; 71.2% of graduate students, 68.8% of undergraduate students), indicated applying/developing teamwork/interpersonal skills as a perceived value of the course.

Applying/developing research, interviewing, and data collection skills and processes was the second most common perceived value coded students' final reflections. Across all three iterations of the course, 60.3% of students (61.3% of male students, 59.5% of female students; 65.0% of engineering students, 53.6% of non-engineering students; 59.6% of graduate students, 62.5% of undergraduate students), indicated applying/developing research, interviewing, and data collection skills and processes as a perceived value of the course.

Applying/developing problem framing and reframing skills and processes, was the third most common perceived value coded in students' final reflections. Across all three iterations of the course, 54.4% of students (64.5% of male students, 46.0% of female students; 55.0% of engineering students, 53.6% of non-engineering students; 55.8% of graduate students, 50.0% of undergraduate students), indicated applying/developing problem framing and reframing skills and processes as perceived value of the course.

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, $X^2(1, N = 68) = 5.14, p < .05$
- Female students were more likely than male students to indicate applying/developing project management and leadership skills as a perceived value, $X^2(1, N = 68) = 4.45, p < .05$
- Female students were more likely than male students to indicate applying/developing client engagement/relationship skills as a perceived value, $X^2(1, N = 68) = 4.45, p < .05$
- Female students were more likely than male students to indicate the applying/developing professional skill sets (theme 2) as a perceived value, $X^2(1, N = 68) = 6.42, p < .05$

A chi-square test of independence showed there was no significant association between student sub-populations: 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 (Carberry et al., 2013; J. Duffy et al., 2008; Huff et al., 2016) 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 (Carberry et al., 2013). Additionally, Wang et al. (2012) 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 (Bani-Hani et al., 2018; Chaparro-Peláez et al., 2013; Jones et al., 2013), 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.

4.4.2.2 Students' Perceived Value – Longitudinal

Based on the frequency with which each code was applied to students' self-reported longitudinal perceived value during the post-course interviews, the prevalence of each theme is shown from most prevalent to least prevalent in the following table. Considering that each theme had varying numbers of subcodes, the comparison analyzes the average frequency of applied codes based on the number of codes in the given theme.

Table 43: Prevalence of Coding Themes – Perceived Value (longitudinal) (N=12 students)

Theme Prevalence	Theme	Frequency	Average Frequency
1. Most Prevalent ↑	Theme 3: Develop/apply design skills/ processes	35	5.8
	Theme 5: Journey for career clarity	17	4.3
	Theme 1: Technical skill sets and discipline-specific knowledge	12	4.0
↓	Theme 2: Develop/apply professional skill sets	19	3.8
5. Least Prevalent	Theme 4: Achieve impact-oriented outcome	15	3.8

The frequency of the three most frequently coded students' longitudinal perceived values, and the percentage of student responses coded, are shown in the following table.

Table 44: Most Frequently Applied Codes to Student Perceived Value - Longitudinal (N=12 students)

Rank	Code	Frequency	Percentage of Students
1	Type of work/project (Theme 5: Journey for career clarity)	10	83.3%
2	Research, Interviewing, Collecting Data (Theme 3: Apply/develop design skills/processes) Design Thinking/Human-Centered Design (Theme 3: Apply/develop design skills/processes)	9	75.0%
3	Ideation and Solution Development (Theme 3: Apply/develop design skills/processes)	7	58.3%

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 conducted one to three years after the completion of the course. From the 12 post-course interviews conducted, which included students from all three iterations of the course, 83.3% of students (75.0% of male students, 87.5% of female students; 66.7% of engineering students, 100% of non-engineering students; 80% of graduate students, 100% of undergraduate students), indicated gaining career clarity regarding the type of work/project as a longitudinal perceived value of the course.

Both applying/developing research, interviewing, and data collection skills and processes and applying/developing Design Thinking/Human-Centered Design skills were the second most common perceived longitudinal values coded in students' post-course interviews. From the 12 post-course interviews conducted, 75.0% of students (50.0% of male students, 87.5% of female students; 50.0% of engineering students, 100% of non-engineering students; 70.0% of graduate students, 100% of undergraduate students), indicated applying/developing research, interviewing, and data collection skills and processes as a longitudinal perceived value of the course. Similarly, 75.0% of students (62.5% of male students, 83.3% of female students; 66.7% of engineering students, 66.7% of non-engineering students; 80.0% of graduate students, 50% of undergraduate students), indicated applying/developing Design Thinking/Human-Centered Design skills as a longitudinal perceived value of the course.

Applying/developing ideation and solution development skills and processes was the third most common longitudinal perceived value coded in students' post-course interviews. From the 12 post-course interviews conducted, 58.3% of students (25.0% of male students, 75.0% of female students; 33.3% of engineering students, 83.3% of non-engineering students; 33.3% of graduate students, 100% of undergraduate students), indicated applying/developing ideation and solution development skills and processes as a longitudinal perceived value of the course.

Due to the low sample size of post-course interviews conducted, a chi-square test of independent was not conducted. These preliminary results provide insight into developing future studies with larger samples sizes.

As students transition to industry and gain experience and exposure working in different environments, they develop additional frameworks to assess value and utility of the outcomes achieved from participating in the course. The post-course interviews conducted with students one to three years after completing the course provide preliminary insight into how students' perceived value of the course may change as they progress in their professional careers. Compared to the prevalence of themes in students' perceived value at the completion of the course, students still highly value the development/application of design skills/processes (Theme 3) but gain an increased value for the career clarity (Theme 5) and the development/application of technical skill sets and discipline knowledge (Theme 1).

Vignettes of four students (of the 12 students interviewed) are provided Section 4.6.3. The progression of each student's motivations, goals, perceived value (end of course), and longitudinal perceived value (one to three years post course) are outlined in each vignette.

4.5 Influence of Social-Impact-Driven, Project-Based Opportunities on Students' Perspectives on Their Future Goals (RQ-4)

4.5.1 Results: Influence of Social-Impact-Driven, Project-Based Opportunities on Students' Perspectives on Their Future Goals (RQ-4)

An interesting concept that emerged from the data was the students gaining perspective and a better understanding of potential career paths moving forward. This theme was prevalent enough in the data that it resulted in Theme 5: Journey for Career Clarity. 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, or the development of students' professional values.

The relative frequency of Theme 5: Career Clarity varied slightly with course iteration, shown in the following figure.

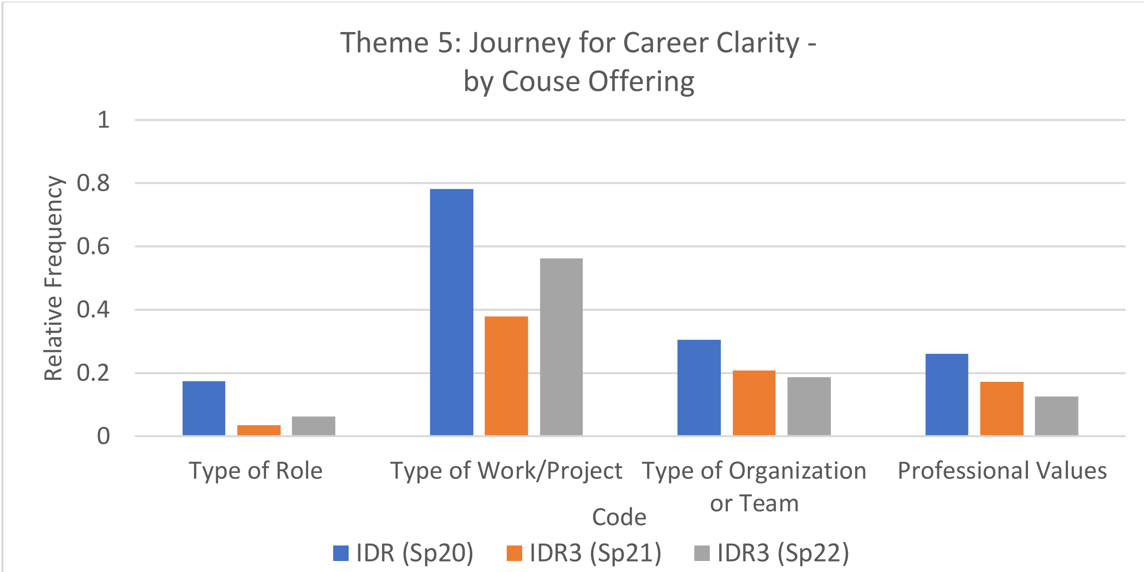


Figure 20: Student Journey for Career Clarity (Theme 5) - by Course Offering

4.5.2 Discussion: Influence of Social-Impact-Driven, Project-Based Opportunities on Students' Perspectives on Their Future Goals (RQ-4) - Discussion

Career clarity presented as both "positive" clarity—confirmation of pre-existing ideas or realization of new possible career path worth pursuing—or "negative" clarity—realization that a potential career path isn't one worth pursuing. Both can be valuable clarifying insights for students regarding their future goals.

Two examples of "positive" career clarity, i.e., confirmation of pre-existing ideas or realization of new possible career path worth pursuing include:

> I was also so excited by the speakers brought into the class, as they brought in really interesting world perspectives about a discipline I didn't even really know about until this class. All the work that Google.org does, and the personal experiences of first responders, and those on the cutting edge of new disaster technology like Loon, it all showed me that there was so much more good that is and can be done in the world, which was both inspiring and a little scary at the same time. It really tilted my focus toward the opportunities in this realm, an avenue I didn't think of pursuing before this, especially with the knowledge of teammates who were already at work in this field. *(IDR-Sp20, female, non-engineering, undergraduate student)*

> The most valuable thing I learned about myself from this course is clarity with regards to what I wish to pursue for my career. For the longest time I only felt

> confusion when thinking about what I wanted to do with my B.A. in Computer Science. I knew I wouldn't be happy simply working for any corporation doing any work even if I were to be making the big bucks. Application is important to me, and that means doing meaningful work. Since a year ago, my passion for all things climate change and environment related bloomed, prompting me to face a new problem—the paradox of too many choices. Computer Science is awesome because it can be applied to practically any field, and now I just had to figure out where I best fit into this puzzle. How and where can my skillset best be utilized to maximize impact in climate change mitigation, adaptation, and resilience? It was a question I struggled with for a long time, but I can finally answer because of this class—I hope to work in Humanitarian Assistance and Disaster Response. *(IDR-Sp20, female, non-engineering, undergraduate student)*

An example of “negative” career clarity, i.e., realization that a potential career path isn’t one worth pursuing include:

> 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. At the end of the semester, designing the UX interface as well as the brochure became more of a task and I felt like it wasn’t something I could do for years to come. In that process, I was constantly thinking about the interviews and hearing stories rather than worrying about the visual design. *(IDR-Sp20, male, non-engineering, undergraduate student)*

Although Career Clarity (Theme 5) was the least prevalent theme in students’ desired outcomes (motivations and goals), the prevalence of Career Clarity in students’ achieved/valued outcomes increased to the third and second most prevalent themes in students’ perceived value and longitudinal perceived value, respectively. More specifically, 12.9% of students indicated at least one motivation related to Career Clarity (Theme 5) in their course application. Furthermore, only 6.3% of students indicated a goal related to Career Clarity as a goal in the goals survey. In contrast, 63.2% of students included at least one perceived value related to Career Clarity in their final reflections. 83.3% of students reported at least one longitudinal perceived value related to Career Clarity during the post-course interviews.

The highest prevalence of Theme 5: Journey for Career Clarity was in the first iteration of the course, Innovation in Disaster Response (Sp20). During this iteration of the course, students completed a series of reflective exercises as part of a “Design your Life” assignment assigned during spring break. Several students explicitly describe the impact of the assignment in their final reflection. The “Design your Life” activity and the positive impact it had was even mentioned by a student during the post-course interview (more than three years after completing the assignment). A student's response in their final reflection calling specific attention to the impact and value of the assignment was as follows:

> For me personally, the most impactful homework assignment was the 'Three Lives Assignment' adapted from the book *Design Your Life*. The assignment initially seemed out of place in our class, but I found the exercise so helpful I actually had my wife do it as well. This exercise helped me to realize that I want to get involved to some degree with a nonprofit. That was my money-is-no-object career, and I realized that meaningful non-profit work can be combined with my full-time engineering work (rather than the either/or approach I previously had). *(IDR-Sp20, male, engineering, graduate student)*

Additionally, the timing of this assignment also coincided with the abrupt transition to remote instruction due to COVID-19. During this time of uncertainty, students may have been more open and receptive to deep self-reflective thought, increasing the personal impact of the assignment.

Although the "Design your Life" assignment was not assigned in subsequent iterations of the course (IDR3-Sp21 and IDR3-Sp22), Career Clarity (Theme 5) continued to be a prevalent theme in students' achieved/valued outcomes, with students most often citing clarity on the type of work/project or type of organization/team during these subsequent offerings of the course. The project sponsors for Innovation in Disaster Response, Recovery, and Resilience (Sp21 and Sp22) were Department of Defense organizations with problems spaces directly related to disaster response, recovery, and resilience efforts. Students acknowledged gaining an understanding of the broader work that some of the groups within the Department of Defense do. Some students cited clarity on their willingness to work with such organizations.

4.5.2.1 Clarity on Type of Role, Type of Work/Project, or Type Organization/Team

Many students cited gaining clarity on the type of work/project that could connect their technical skill sets and their desire to work on meaningful projects. The quote from one student's final reflection even highlights the fact they didn't think their technical background and passion for environmental change could be combined for a potential career path to pursue. The student remarks that this course provided them clarity on possible career paths forward combining these two passions.

> To begin with, this class turned out to be rather different from what I expected. I was expecting to design some random commercial product by incorporating design thinking, but instead I turned a new leaf in my professional career. I am an environmental and climate change activist from a mechanical engineering product design background who was sure these two were [in] no way compatible for a

> career. But through this course I discovered that design thinking is a tool that can be used to evaluate life and social problems. *(IDR-Sp20, male, engineering, graduate student)*

The following excerpt from another student's final reflection also indicates the course provided clarity on the type of work they would like to pursue utilizing their technical skill.

> I learned a lot about myself. Before this class, I was pretty confused about what I wanted to do. I had just joined Blueprint (an org on campus that helps develop software pro bono for nonprofits) and this class in an attempt to broaden my horizons with what I could do in the future. Over the duration of this course, being able to prototype something really tangible that could help NTSB investigators document aircraft crashes and listening to all the guest speakers inspired me to try and apply my technical skills to important issues throughout the world today. Though I may have a lot of learning to do, both technically and in these different disaster response fields, I know that I want to get into the field of Humanitarian Assistance and Disaster Response today (something I didn't even know about 5 months ago!). I cannot wait to be able to apply what I've learned to future endeavors I'll pursue in this space, and hopefully, be able to inspire and teach so many others about how we can take action and focus in on how we can help our communities focus on tackling different problems/pain points they face today. *(IDR-Sp20, male, non-engineering, undergraduate student)*

In the second and third iteration of the course, Innovation in Disaster Response, Recovery and Resilience (Sp21 and Sp22), the problem spaces were sourced in collaboration with the National Security Innovation Network and the Department of Defense's Hacking4Defense program. All problem spaces selected for the course were directly related to disaster response, recovery, and resilience efforts; however, project sponsors were members from various Department of Defense organizations. Clarity on the type of organization/team most frequently resulted from students' gaining clarity on the types of organizations within the Department of Defense that support disaster response and recovery efforts and the possibility of including such an organization during future job searches, as indicated in the excerpt of a student's final reflection below.

> Admittedly I was a little hesitant about working closely with a DoD sponsored project as military related stuff doesn't really align with my interests. However, learning of all the different projects and possibilities related to disaster response through my classmates and guest speakers opened my eyes to all of the events DoD encompasses and responds to. This was encouraging to me as someone who wants to get more involved in this field! Similarly, I really enjoyed knowing that there is a strong need for technology and engineering for all types of disaster response. 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. Listening to the work out there and up and coming developments inspired me to seriously consider this in my job search. *(IDR3-Sp21, female, engineering, graduate student)*

Although not as frequently, students also gained clarity on the type of role they would or would not like to pursue in their professional careers. Many of the graduate students who took the course were part of the Master of Engineering (MEng) program which aims to combine technical expertise with business and management skills. Many of the students participating in the professional master's program are at a point in their professional careers where they have had some prior industry experience and are looking to develop certain skill sets to progress toward more leadership and managerial positions. This following excerpt from a student's final reflection is an example of a student gaining clarity on the type of role they would like to pursue professionally.

> This course also helped confirm for me that I want to follow the managerial path in my career, rather than a technical path. 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. *(IDR-Sp20, female, engineering, graduate student)*

In contrast, another student gained clarity on their preference to not take a leadership role, if possible.

> Through the teamwork component, I confirmed my belief that I work best when I am not the project manager, but when I have an exceedingly high degree of confidence in the project manager. However, I am not quick to fully trust others to project manage, putting myself in a bit of a Catch-22. I need to do a better job of letting go and trusting others to take the lead. If I do choose to take the lead, I need to recognize that it was my own choice and not feel resentful of the added responsibility. *(IDR-Sp20, female, non-engineering, graduate student)*

4.5.2.2 Development of Professional Values

Professional values included concepts such as (i) examining beliefs and values and how they influence ethical decision making, (ii) value of diversity, (iii) ethical issues in engineering practice, and the (iv) importance of lifelong learning (Lattuca et al., 2014).

In the excerpts from two different student final reflections below, both students express the value of diversity and the significant role it played in the success of their projects.

> This course really hit home for me the importance of a diverse skill set and group. The final presentation is likely the most polished presentation aesthetics-wise I've ever been a part of – because two of our group members excelled at graphic design. My group leveraged not only our different educational skill sets, but also our different cultures and connections to really find a remarkable solution. *(IDR-Sp20, female, engineering, graduate student)*

> The interdisciplinary nature of my team, as well the project itself helped me learn from people from different background approach the same problem. And why that is a good thing. I am confident I would have come up with a completely different idea, or even if one person was missing in the team, our solution would be vastly different. This has made me appreciate the value of diversity. *(IDR3-Sp21, male, engineering graduate student)*

Students also expressed an understanding of the ethical responsibly that comes with engineering and designing solutions through their experience working on the course project. In the excerpt below, the student mentions a sense of responsibility being developed as they engaged with disaster survivors while working on their project. The student also goes on to express their recommendation for all students to take a course that teaches not only technical concepts, but also social responsibility.

> It was an enlightening experience to talk to disaster survivors and learn about the incident piece by piece, which did create a sense of responsibility in all of us. (…) In a nutshell I would suggest every incoming student irrespective of their department to be a part of a class that teaches core technical topics as well as social responsibility. *(IDR-Sp20, male, engineering, graduate student)*

Finally, in the excerpt below an engineering student clearly recognizes that the solutions developed by engineers have the potential to impact a large group of people. The student acknowledges their responsibility as an engineer and pledges to ensure solutions they develop will not have negative impacts.

> Going forward, I don't really intend to go further with [our project] or into Disaster Response directly – but as an engineer, anything I make or design or take part in has the potential to impact a far wider range of people than most project circles consider. What I want to take from this class is how to ensure whatever I do doesn't worsen any situations – disaster related or otherwise – even if it's not directly helpful. *(IDR-Sp20, female, engineering, graduate student)*

4.6 The Evolution of Students' Desired and Achieved Outcomes During Social-Impact-Driven, Project-Based Learning Opportunities (RQ5)

4.6.1 Results: The Evolution of Students' Desired and Achieved Outcomes During Social-Impact-Driven, Project-Based Learning Opportunities (RQ5)

Students' motivations, goals, and perceived value were collected at four junctures before, during, immediately after, and one to three years after the PBSL experience. Students' responses to their motivations for taking the course were collected before the start of the semester. Students' responses for the goals that they set for the semester and their project were collected at the beginning of the semester. Students' responses for their perceived value of the course were collected after the completion of the course. Given the timing student responses were solicited, the students' motivations and goals are considered to be their desired outcomes and the students' reported perceived values are considered to be their achieved outcomes.

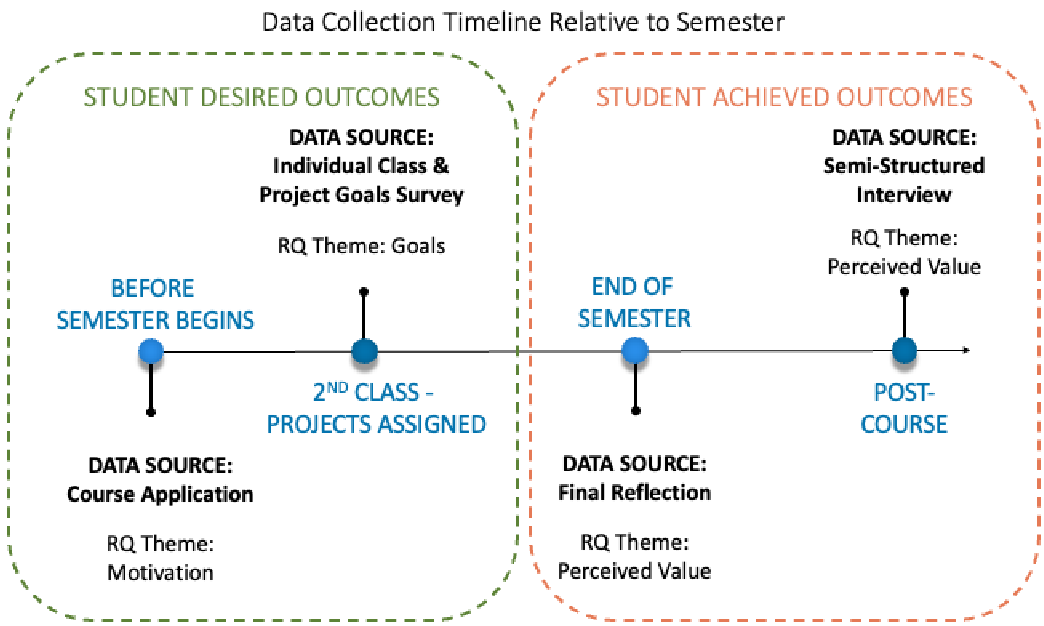


Figure 21: Student Desired Outcomes and Achieved Outcomes - Data Collection Timeline

Based on the frequency with which each code was applied to student responses for each data source, the prevalence of each theme in student responses is shown from most prevalent to least prevalent in the following table. Considering that each theme had varying numbers of subcodes (varying from three to six subcodes per theme), the comparison analyzes the frequency of applied codes for each theme relative to the number of codes in the given theme.

Table 45: Prevalence of Themes, Motivations, Goals, Perceived Value

Theme Prevalence	STUDENT DESIRED OUTCOMES		STUDENT ACHIEVED OUTCOMES
	Motivations (DS-1)	Goals (DS-2)	Perceived Value (DS-3)
1. Most Prevalent	Theme 4: Achieve impact-oriented Outcome (n=79)	Theme 4: Achieve impact-oriented outcome (n=64)	Theme 3: Develop/apply design skills/ processes (n=170)
	Theme 1: Technical skill sets and discipline-specific knowledge (n=40)	Theme 2: Develop/apply professional skill sets (n=64)	Theme 2: Develop/apply professional skill sets (n=113)
	Theme 3: Develop/apply design skills/ processes (n=43)	Theme 1: Technical skill sets and discipline-specific knowledge (n=34)	Theme 5: Journey for career clarity (n=70)
	Theme 2: Develop/apply professional skill sets (n=25)	Theme 3: Develop/apply design skills/ processes (n=50)	Theme 1: Technical skill sets and discipline-specific knowledge (n=44)
5. Least Prevalent	Theme 5: Journey for career clarity (n=10)	Theme 5: Journey for career clarity (n=4)	Theme 4: Achieve impact-oriented outcome (n=40)

The following graph shows the percentage of student responses coded with at least one code from each coding theme for each data source.

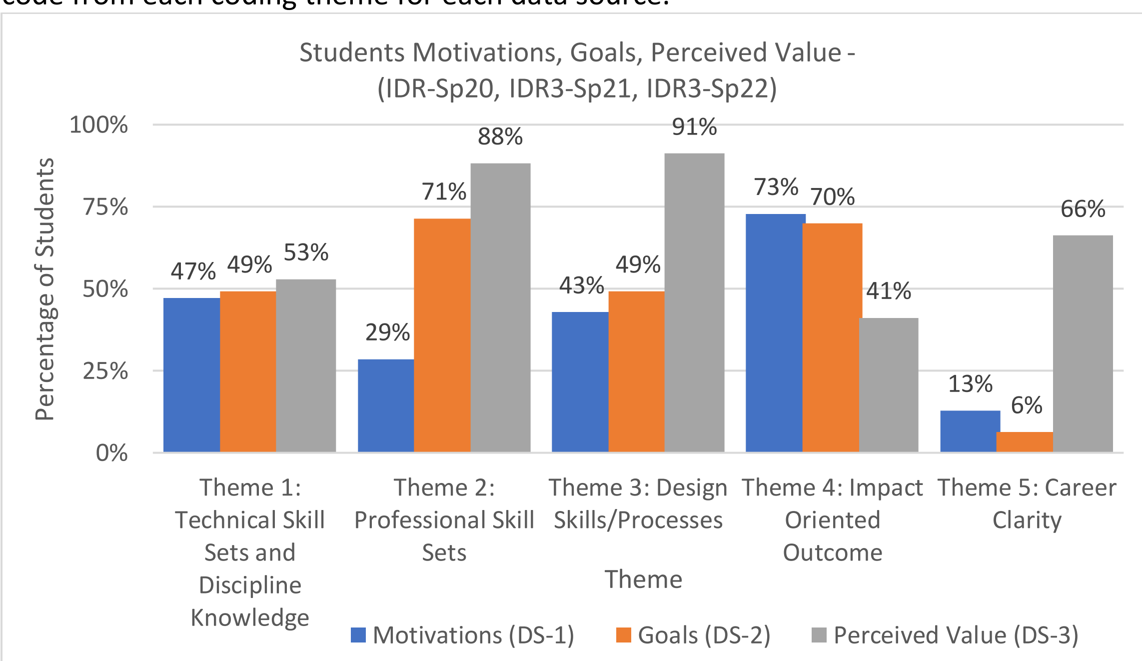


Figure 22: Student Motivations, Goals and Perceived Value - by Course Offering

Comparing students' desired outcomes at the beginning of the course (motivations and goals) and their achieved outcomes reported at the conclusion of the course (perceived value), some variation between students' desired outcomes and achieved outcomes are observed, most generally for Theme 2: Development/Application of Professional Skill Sets, and for Theme 3: Development/Application of Design Skills/Processes, and Theme: Career Clarity.

To illustrate how the prevalence of each theme varied among student motivations (DS-1), goals (DS-2), and perceived value (DS-3 and DS-4), the relative frequency of each theme for each data source is shown in the following graph.

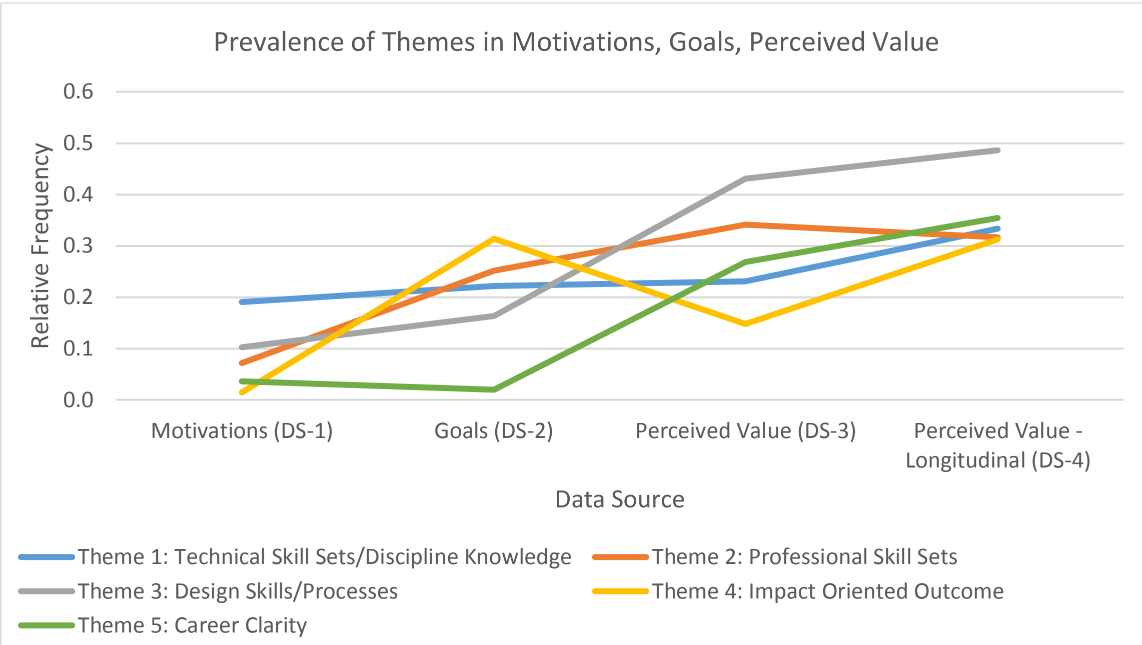
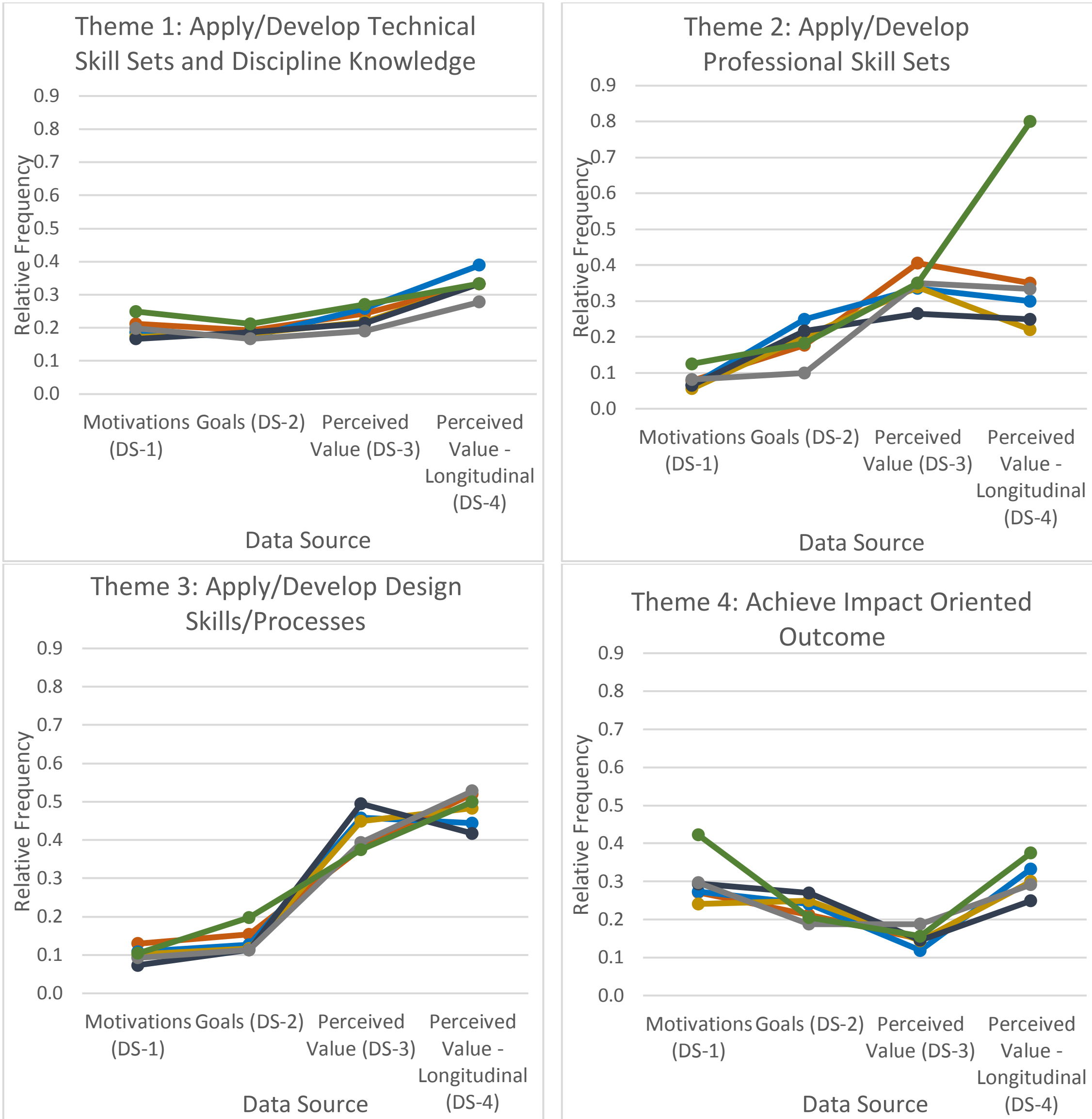


Figure 23: Variation of Theme Prevalence in Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), and Longitudinal Perceived Value (DS-4)

To explore any possible differences in how prevalence of each theme may have varied among data sources for different student populations (i.e., by gender, discipline, and class standing), the following graphs depict the prevalence of each theme for different student populations.


Theme 1: Apply/Develop Technical Skill Sets and Discipline Knowledge
Relative Frequency
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Motivations (DS-1)
Goals (DS-2)
Perceived Value (DS-3)
Perceived Value - Longitudinal (DS-4)
Data Source
Theme 2: Apply/Develop Professional Skill Sets
Relative Frequency
Motivations (DS-1)
Goals (DS-2)
Perceived Value (DS-3)
Perceived Value - Longitudinal (DS-4)
Data Source
Theme 3: Apply/Develop Design Skills/Processes
Relative Frequency
Motivations (DS-1)
Goals (DS-2)
Perceived Value (DS-3)
Perceived Value - Longitudinal (DS-4)
Data Source
Theme 4: Achieve Impact Oriented Outcome
Relative Frequency
Motivations (DS-1)
Goals (DS-2)
Perceived Value (DS-3)
Perceived Value - Longitudinal (DS-4)
Data Source

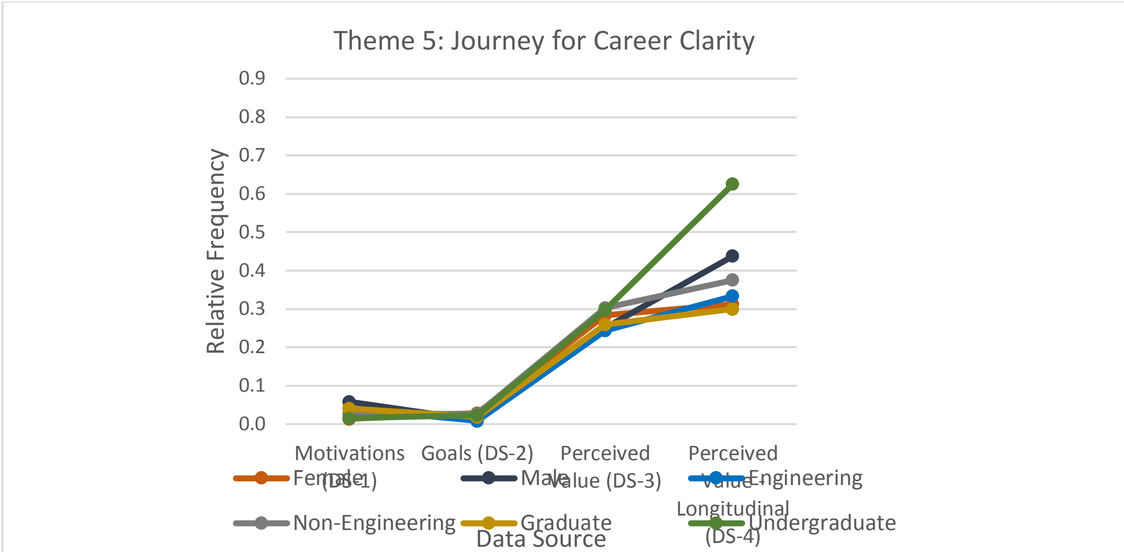
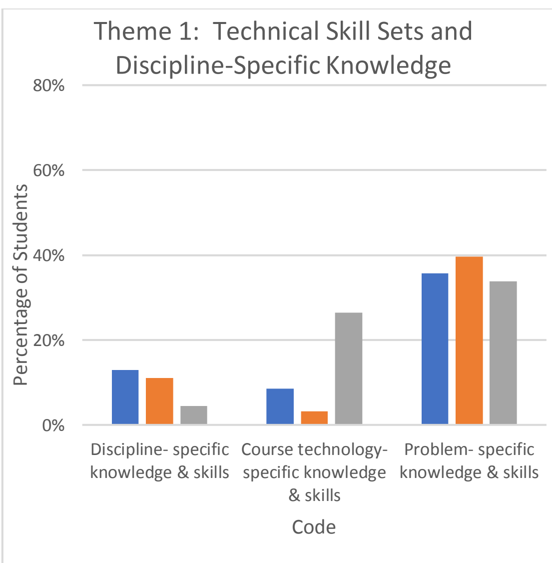
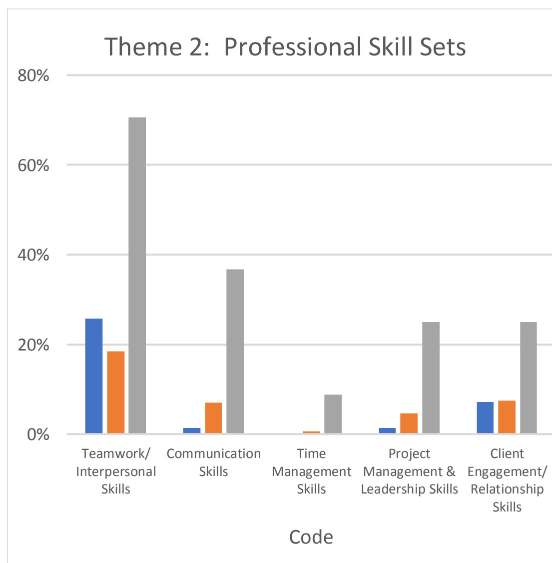


Figure 24: Variation of Theme Prevalence in Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), and Longitudinal Perceived Value (DS-4) - by Gender, Discipline, and Class Standing

The following graphs show the comparison of students' motivations, goals, and perceived value for each individual theme.





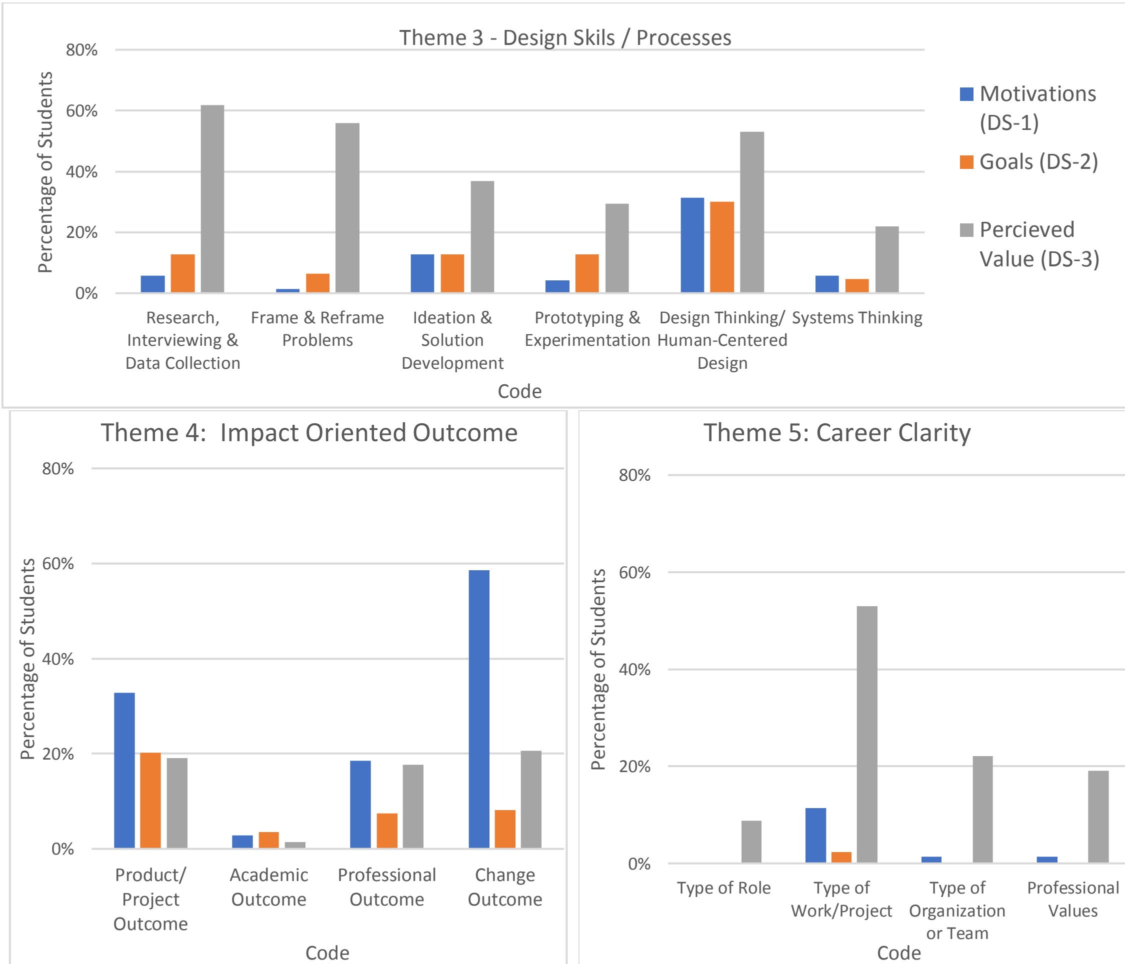


Figure 25: Student Motivations (DS-1), Goals (DS-2), and Perceived Value (DS-3) - by Theme

The following table lists the most and least frequently applied codes to student responses indicating their desired outcomes (i.e., motivations and goals) and achieved outcomes (i.e., perceived value).

Table 46: Most and Least Commonly Applied Codes to Student Responses (IDR-Sp20; IDR3-Sp21; IDR3-Sp22)

	STUDENT DESIRED OUTCOMES				**STUDENT ACHIEVED OUTCOMES**	
	Motivations (DS-1)		Goals (DS-2)		Perceived Value (DS-3)	
3 Most Coded Student Responses	Change outcome – Th 4	(n=41)	Change outcome – Th 4	(n=33)	Teamwork/interpersonal skills – Th 2	(n=48)
	Product/project outcome – Th 4	(n=23)	Teamwork/interpersonal skills – Th 2	(n=30)	Research, interviewing, and data collection – Th 3	(n=41)
	Problem-specific knowledge and skills – Th 1	(n=25)	Problem-specific knowledge and skills – Th 1	(n=25)	Frame and Reframe problems – Th 3	(n=37)
3 Least Coded Student Responses	Academic outcome – Th 4	(n=2)	Course technology-specific knowledge and skills – Th 1	(n=2)	Time management – Th2 Type of role – Th 5	(n=6)
	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)	Discipline-specific knowledge and skills – Th 1	(n=3)
	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)	Academic outcome – Th 4	(n=1)

4.6.1.1 Student Motivations, Goals, and Perceived Value – by Gender

The following graph compares the prevalence of each theme in coded responses for student motivations (DS-1), goals (DS-2), and perceived value (DS-3 and DS-4) between male and female students.

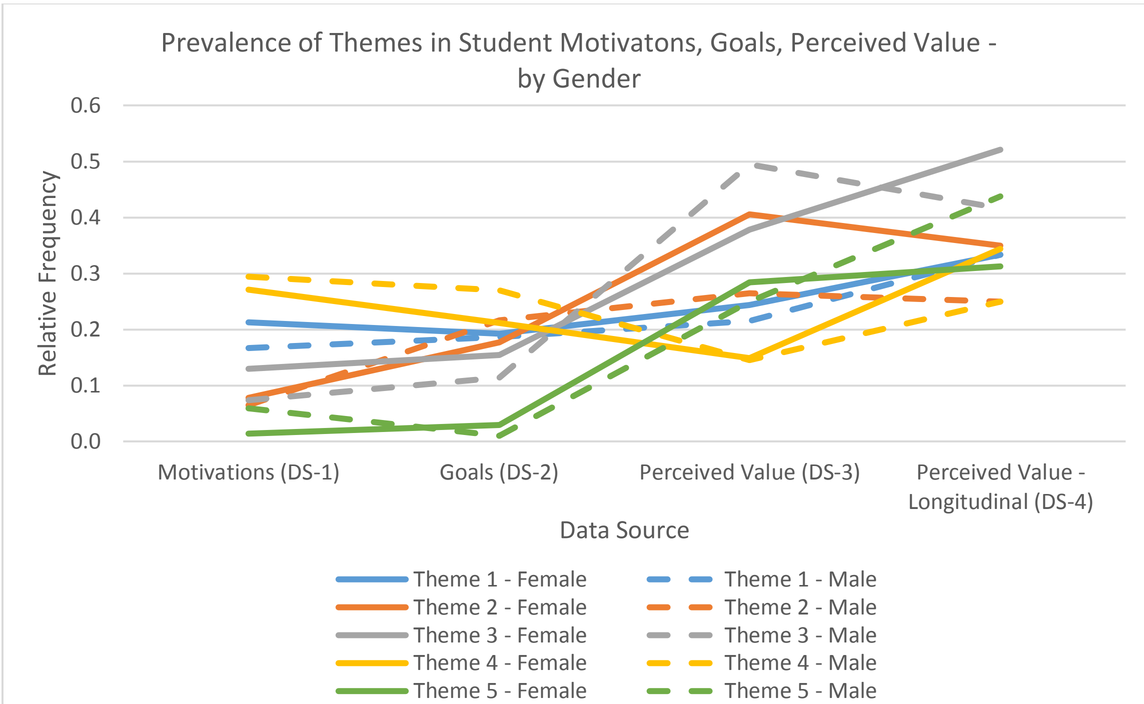


Figure 26: Variation of Theme Prevalence in Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), and Longitudinal Perceived Value (DS-4) – by Gender

4.6.1.2 Student Motivations, Goals, and Perceived Value – by Discipline

The following graph compares the prevalence of each theme in coded responses for student motivations (DS-1), goals (DS-2), and perceived value (DS-3 and DS-4) between engineering and non-engineering students.

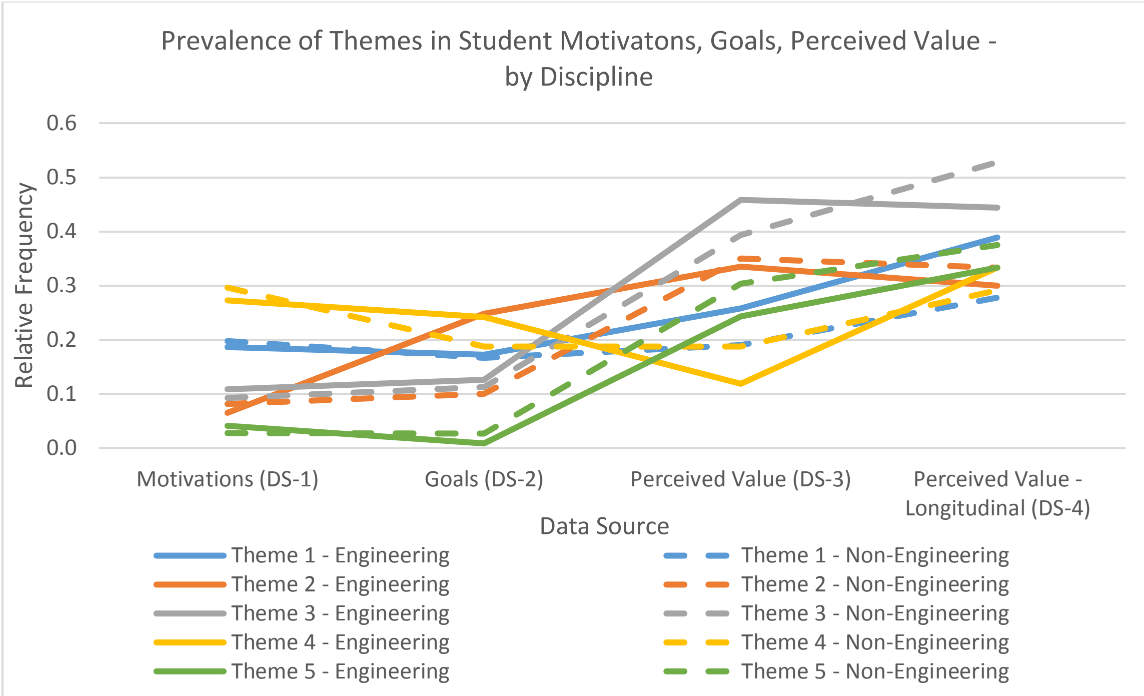


Figure 27: Figure 26: Variation of Theme Prevalence in Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), and Longitudinal Perceived Value (DS-4) – by Discipline

4.6.1.3 Student Motivations, Goals, and Perceived Value – by Class Standing

The following graph compares the prevalence of each theme in coded responses for student motivations (DS-1), goals (DS-2), and perceived value (DS-3 and DS-4) between graduate and undergraduate students.

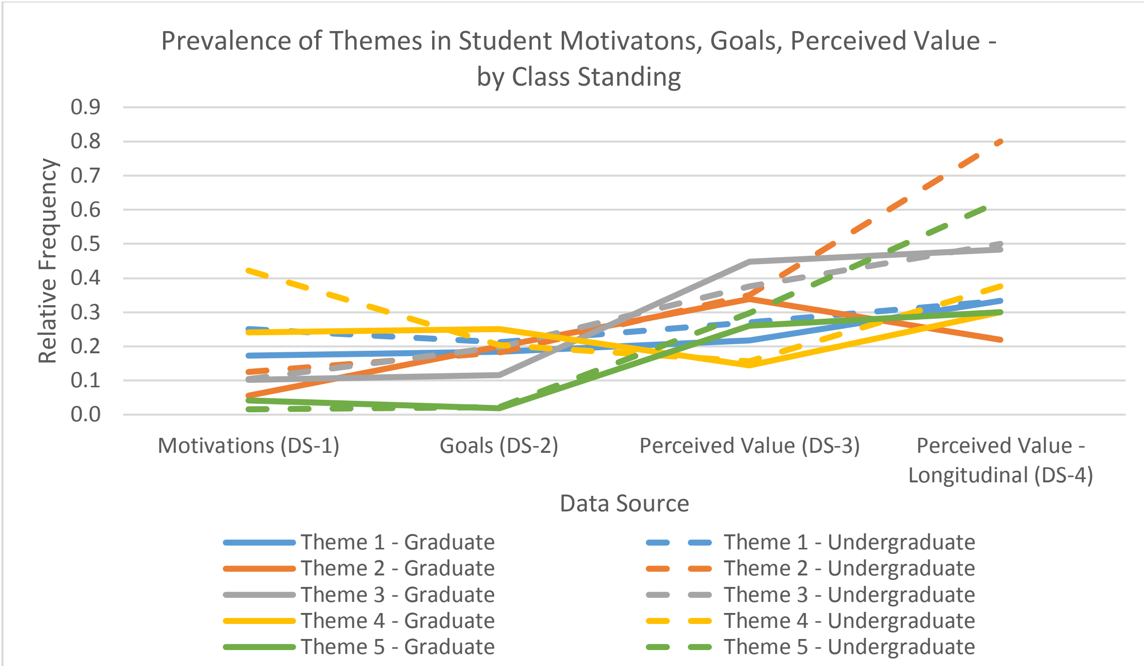


Figure 28: Figure 26: Variation of Theme Prevalence in Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), and Longitudinal Perceived Value (DS-4) – by Class Standing

4.6.2 Discussion: The Evolution of Students' Desired and Achieved Outcomes During Social-Impact-Driven, Project-Based Learning Opportunities (RQ5)

The following table compares students' desired outcomes (motivations and goals) at the beginning of the semester and their achieved outcomes (perceived value, longitudinal perceived valued) reported at the conclusion of the course and one to three years after the conclusion of the course. Some differences between students' desired outcomes and achieved outcomes were observed and are indicated in grey.

Table 47: Prevalence of Themes, Motivations, Goals, Perceived Value

Theme Prevalence	STUDENT DESIRED OUTCOMES		STUDENT ACHIEVED OUTCOMES	
	Motivations (DS-1)	Goals (DS-2)	Perceived Value (DS-3)	Perceived Value - Longitudinal (DS-4)
1. Most Prevalent	Theme 4: Achieve impact-oriented Outcome (n=79)	Theme 4: Achieve impact-oriented outcome (n=64)	Theme 3: Develop/apply design skills/ processes (n=170)	Theme 3: Develop/apply design skills/ processes (n=35)
	Theme 1: Technical skill sets and discipline-specific knowledge (n=40)	Theme 2: Develop/apply professional skill sets (n=64)	Theme 2: Develop/apply professional skill sets (n=113)	**Theme 5: Journey for career clarity (n=17)**
	Theme 3: Develop/apply design skills/ processes (n=43)	Theme 1: Technical skill sets and discipline-specific Knowledge (n=34)	**Theme 5: Journey for career clarity (n=70)**	Theme 1: Technical skill sets and discipline-specific knowledge (n=12)
	Theme 2: Develop/apply professional skill sets (n=25)	Theme 3: Develop/apply design skills/ processes (n=50)	Theme 1: Technical skill sets and discipline-specific knowledge (n=44)	Theme 2: Develop/apply professional skill sets (n=19)
5. Least Prevalent	**Theme 5: Journey for career clarity (n=10)**	**Theme 5: Journey for career clarity (n=4)**	Theme 4: Achieve impact-oriented outcome (n=40)	Theme 4: Achieve impact-oriented outcome (n=15)

Noting how the prevalence of themes changes considerably between students' motivations and goals and their 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). For example, based on students' motivations and goals, the desire to achieve an impact-oriented outcome (Theme 4) was the top theme for desired course outcomes. However, achieving an impact-oriented outcome (Theme 4) was the least prevalent theme in students' reported/achieved outcomes (perceived value). More specifically, 47.1% and 72.9% of students indicated at least one motivation related to Theme 1 and Theme 4, respectively, in their course application. Similarly, 49.2% and 69.8% of students indicated at least one goal related to Theme 1 and Theme 4, respectively, in the goals survey.

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 were overwhelmingly positive and included comments from students such as the ones included below.

> This class has been one of my best experiences at my short 10 months in [University Name]! It was amazing to be with people who know so much about disaster response and working with so many innovative people and students. (…) Thank you for this amazing course and I really hope [University Name] continues to offer this course in the future. *(IDR-Sp20, male, engineering, graduate student)*

> First off, I wanted to say that this class was hands down the best one I've taken in my college years, even given the COVID-19 shaped wrench in the plans. I had a vague sense going in that I liked to design things, the sort of idea that I wanted to make things to help people as much as I possibly could. But this class has been such an eye opener in terms of real, tangible facts and inspiration in that realm. I had no idea I would come out of this [class] knowing things like how to make a simple VR prototype, or use fancy data representation software, or learn how a drone works and is used and can be used in the future. *(IDR-Sp20, female, non-engineering, undergraduate student)*

> Thank you for making this class so amazing. You guys have really helped inspire me to take initiative and begin shifting my career direction toward social good! I can't wait to see what else lies in store for me as I continue heading down this journey. (IDR-Sp20, male, non-engineering, undergraduate student)

> I'll hold on to this class as a special experience for years. Having a definitive problem and solution path that (probably) will be implemented in the military is a great story and portfolio piece to have, but the less tangible experiences of need finding, and stakeholder management are skills that will be generally useful for my life and career. In addition, I expanded my professional network and learned through both the project and lectures. The teaching team was very effective at conveying information, and I felt that I learned a lot of new material quickly. I hope you run this course again so that other students can have the same experience I did. *(IDR3-Sp21, male, engineering, graduate student)*

> I would like to start with appreciation for this class. It is the class that I took as an elective for the Master of Development Engineering program. Being an elective, it was completely my choice and I am very happy I did. *(IDR3-Sp22, female, engineering, graduate student)*

Students' motivations and goals are captured early in their interaction with the course. During these initial periods of the courses, Theme 1: Apply/develop technical skill sets and content knowledge and Theme 4: Achieve impact-oriented outcome are more prominent in students' desired outcomes. These 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. 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, such as project management skills or improved communication skills, that may not initially come to mind when students are assessing the different learning opportunities that the course/project could potentially provide them throughout the semester. 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 indicates that students identified these as a valuable outcome from the course.

Theme 5: Journey for career clarity is another theme that showed a large variation in prevalence across students' motivations, goals, perceived value. Theme 5 was the least prevalent theme in students' motivations and goals. In fact, codes from this theme were coded in only 10 student motivation responses and four student goal responses. In contrast, 70 student final reflections were coded for responses related to career clarity, making Theme 5 the third most prevalent theme in students' perceived value and second most prevalent themes in students' longitudinal perceived value.

4.6.3 Student Vignettes

Sections 4.6.1.1 to 4.6.1.4 focus on vignettes from four students (of the 12 students interviewed). Since the post-course interviews (DS-4) were intended to explore students' perceived value of the course after transition to professional practice, all four vignettes are from students who took the course as graduate students and worked in industry after the completing the course.

Table 48: Student Vignettes - Student Information

Student	Course	Gender	Discipline	Class Standing (at time of course)
Student A	IDR-Sp20	Male	Engineering	Graduate
Student B	IDR3-Sp21	Female	Non-Engineering	Graduate
Student C	IDR-Sp20	Male	Engineering	Graduate
Student D	IDR-Sp22	Female	Engineering	Graduate

4.6.3.1 Vignette 1: Student A (IDR-Sp20, Male, Engineering, Graduate Student)

Student A was part of the one-year Master of Engineering (MEng) program when he enrolled in Innovation in Disaster Response in Spring 2020. Since completing the course and graduating from the MEng program in Spring 2020, Student A worked as a Senior Manufacturing Engineer at a global healthcare company developing innovative medical solutions for one year. He has worked at a company developing electric motorcycles as a Mechanical Design Engineer for two years. Student A is currently working as a Research Scientist at a federal research center. The post-course interview was conducted almost three years after completing the course.

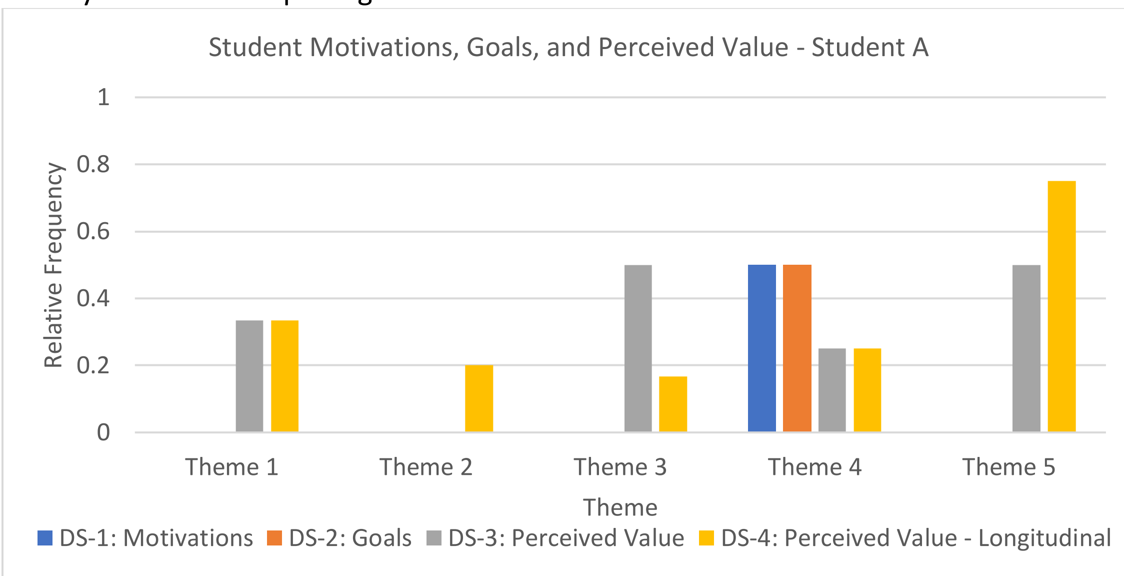


Figure 29: Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), Longitudinal Perceived Value (DS-4), by Theme - Student A

To understand how Student A's desired outcomes (i.e., motivations (DS-1) and goals (DS-2)) and achieved outcomes (i.e., perceived value (DS-3) and longitudinal perceived value (DS-4)) may have varied, the codes present in Student A's responses across all four data sources are listed in the following table.

Table 49: Student Motivations, Goals, Perceived Value – Student A

STUDENT DESIRED OUTCOMES		STUDENT ACHIEVED OUTCOMES	
Motivations (DS-1)	Goals (DS-2)	Perceived Value (DS-3)	Perceived Value – Longitudinal (DS-4)
Product/project outcome—Th 4 Change outcome—Th 4	Product/project outcome—Th 4 Change outcome—Th 4	Course technology-specific knowledge and skills—Th 1 Research, interviewing, and data collection—Th 3 Frame and reframe problems—Th 3	Problem-specific knowledge and skills—Th 1 Teamwork/ interpersonal skills—Th 2 Design Thinking/ Human-Centered Design—Th 3

		Design Thinking/ Human-Centered Design—Th 3 Product/project outcome—Th 4 Type of work/project—Th 5	Change outcome— Th 4 Type of work/ project—Th 5 Type of organization/ team—Th 5 Professional values—Th 5

When talking about his professional path to date, Student A expressed that he has been exploring different companies to find the right fit for him, providing insight into his journey for career clarity.

> It's been quite a twisting and turning path towards where I am right now. But it did take me two and a half, three years. Even now, it's still taking me time to kind of set myself in the right path, to explore, to learn where I fit well. So that's why I've been jumping across different companies. So, yeah, mostly I would say I've been exploring, moving from company to company, seeing where I fit well.

When asked what he was searching for, Student A indicated he was searching for meaningful and challenging work, indicated in the following quote:

> I'd say I'm looking for meaning. I'm looking for something that will allow me to go to work every day excited. That challenges me every single day. And that's one of the reasons why I wanted to move more toward research, because research is more like, hey, let's do this and let's see what happens. Or, let's try this and let's see what happens. It's all about curiosity. (...) But these companies, they're more commercial. It's like, make the most money. Make this design or design something that's cheaper, that's efficient, and things like that, that's become very stale for me. One year I've been in these companies, even different teams: R&D teams, the quality teams, just the mechanical engineering teams, they all are very stale, unidirectional. There's no real challenge in it. That's only doing one thing over and over in different ways. At the end of the day, you're only building bikes. You're only building different bikes. The bike in different ways. There's nothing really new. (…) But I've always been a person, even in interviews I tell them, I don't care about how much you pay me. I care about the work. It has to be challenging. And if it's not challenging, I'm off in one year. I'm just looking for that real connection with the work, because I want to go to work, not, oh, shit, it's Monday again. Right. I really want to go there and be like, oh, wow, we're tackling something new.

Later in the interview, Student A shared that participating in the course contributed to his journey for career clarity (Theme 5) by showing him that his technical skillsets could be used for humanitarian causes.

> One major thing that I would say that I learned is how my skill set can be used directly for humanitarian causes. That's something that I've never, ever thought of. I was always a person about I was an environmentalist. I used to go to these deforestation campaigns, forestation campaigns and beach cleanup campaigns. I was that guy. I was all about the environment. But humanitarian, it's a little bit more human centric. And that thing where I learned my skill set can be directly useful to these disaster management type of scenarios.

Student A continued to further explain how the course contributed to his career clarity (Theme 5) by providing tangible opportunities for him to use his discipline-specific knowledge and skills (i.e., mechanical engineering skills) within disaster management while working on the course project (Theme 1).

> I was able to use my skills such as structural analysis. Structural analysis. I'm a mechanical engineer. I use structural analysis for when a car crash happens. Is a human safe inside? Like the structural integrity of a car? But then I was able to use that for different materials and I was able to dive deep into these materials. And if these houses are standing on some sort of a foundation of pillars, if there's an earthquake again, if there's a flood again, will it be able to withstand that? So, I was able to use that in a really unique way, which I never thought might be I would be able to use so many other logistical things.

4.6.3.2 Vignette 2: Student B (IDR3-Sp21, Female, Non-Engineering, Undergraduate)

Student B was a master's student in Landscape Architecture when she enrolled in Innovation in Disaster Response, Recovery and Resilience in Spring 2021. Since completing the course and graduating with her master's degree in Spring 2021, she worked as UX designer at a global software company developing enterprise business management software for just under two years and is currently working as a UX designer in the manufacturing industry. The post-course interview was conducted almost two years after completing the course.

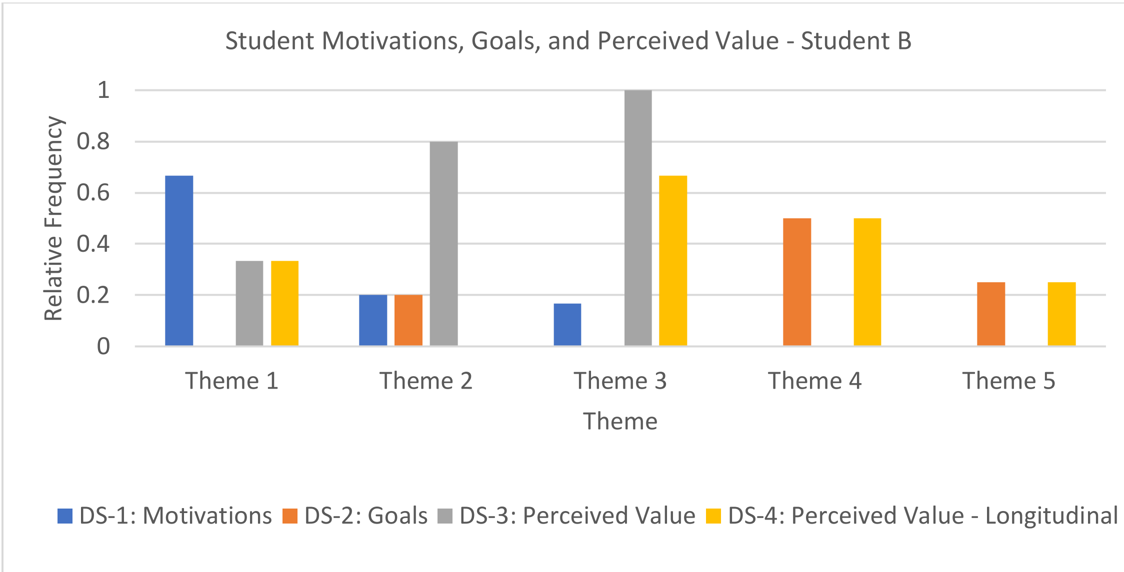


Figure 30: Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), Longitudinal Perceived Value (DS-4), by Theme - Student B

To understand how Student B's desired outcomes (i.e., motivations (DS-1) and goals (DS-2)) and achieved outcomes (i.e., perceived value (DS-3) and longitudinal perceived value (DS-4)) may have varied, the codes present in Student B's responses across all four data sources are listed in the following table.

Table 50: Student Motivations, Goals, Perceived Value – Student B

STUDENT DESIRED OUTCOMES		**STUDENT ACHIEVED OUTCOMES**	
Motivations (DS-1)	Goals (DS-2)	Perceived Value (DS-3)	Perceived Value – Longitudinal (DS-4)
Course technology-specific knowledge and skills—Th 1 Problem-specific knowledge and skills—Th 1 Teamwork/ interpersonal skills—Th 2 Design Thinking/ Human-Centered Design—Th 3	Teamwork/ interpersonal skills—Th 2 Product/project outcome—Th 4 Professional outcome—Th 4 Type of work/ project—Th 5	Problem-specific knowledge and skills—Th 1 Teamwork/ interpersonal skills—Th 2 Communication skills—Th 2 Time management skills—Th 2 Client engagement/ relations skills—Th 2	Discipline specific knowledge and skills—Th 1 Research, interviewing, and data collection—Th 3 Frame and reframe problems—Th 3 Ideation and solution development—Th 3 Design Thinking/ Human-Centered Design—Th 3

		Research, interviewing, and data collection—Th 3 Frame and reframe problems—Th 3 Ideation and solution development—Th 3 Prototyping and experimentation— Th 3 Design Thinking/ Human-Centered Design—Th 3 Systems Thinking—Th 3	Product/project outcome— Th 4 Professional outcome— Th 4 Type of work/ project—Th 5

When discussing her professional path and career since graduating, Student B remarked that although her major, Landscape Architecture, isn't the typical major for a UX designer, she knew she wanted to make a change to her professional trajectory toward something like UX design and shared her motivations and desired outcomes for taking the course were to develop design skills (Theme 3) and develop a portfolio-worthy project (Theme 4).

> One of my intentions to attend this class, because when I was in [University Name], my major is landscape architecture. That's not the exact major for UX designer. So, I want to take something more related to UX design, like user centered design, and to collect some projects for my portfolio.

Student B also shared that she did not include the prototype developed as part of the course project in her portfolio since the final prototype did not have the level of user feedback and user testing that is typically expected for product development in her current industry. She did acknowledge that the virtual instruction and limited in person interaction due to the ongoing COVID-19 pandemic may have contributed to the limited user testing for the final prototype.

> Unfortunately, I didn't put the project for this class in my portfolio, although it had good impact. But I think constrained by the virtual class and the online collaboration, we don't make some very practical or how to say, like, very useful final or physical deliverables. So that's the reason I don't put it in my portfolio.

When asked to expand, Student B shared that a lack of opportunities to directly observe and interact with the end users the solution was being developed for resulted in a final prototype that she felt wasn't very practical or useful. This lack of direct user feedback was ultimately the reason why she did not include the class project in her portfolio. She specifically expressed being limited to only stakeholder interviews to research and identify the problem her team was solving.

> [Since] our users are in the Navy, we cannot really visit them to figure out what their real issues in their daily life because everything we get is from the conversation. So, I think that's one of the limitations. I also saw some groups to have an onsite visit to test their final designs in the real situation, but we don't have that opportunity to do that.

4.6.3.3 <u>Vignette 3: Student C (IDR-Sp20, Male, Engineering, Graduate Student)</u>

Student C was part of the one-year Master of Engineering (MEng) program when he enrolled in Innovation in Disaster Response in Spring 2020. Since completing the course and graduating from the MEng program in Spring 2020, Student C first started working at a civil engineering firm creating 3-D models of sewer pipelines and mapping data to support maintenance and modernization efforts. Student C worked as a Reliability Engineer at a global technology company that develops consumer electronics, computer software, and personal computers for several months before transitioning to his current role as a System Test Engineer at a small company developing a fully automated fulfilment system to increase sustainability and profitability. The post-course interview was conducted almost three years after completing the course.

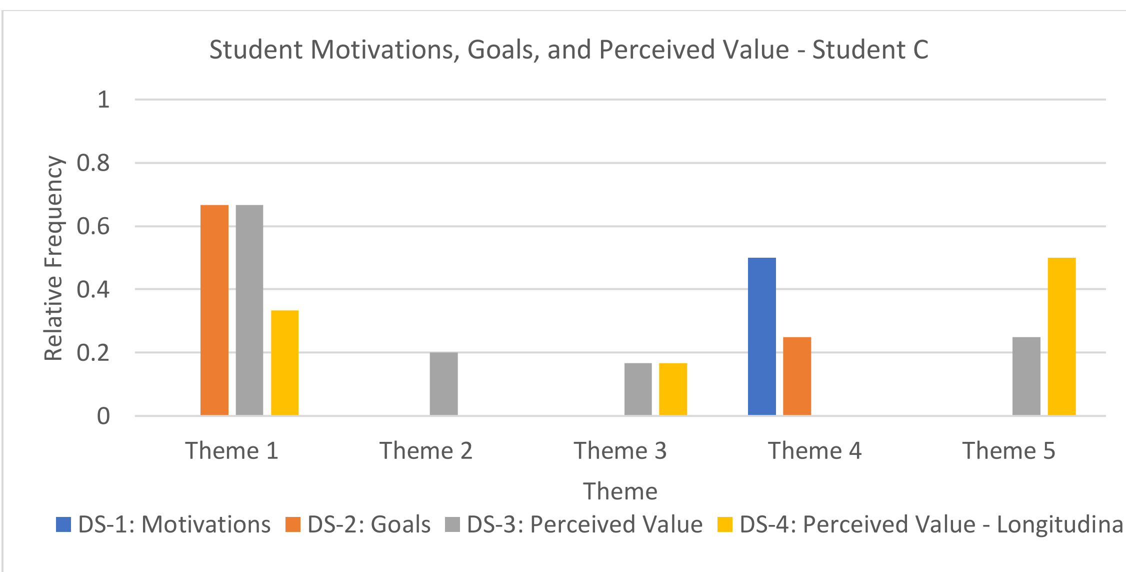


Figure 31: Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), Longitudinal Perceived Value (DS-4), by Theme - Student C

To understand how Student C's outcomes (i.e., motivations (DS-1) and goals (DS-2)) and achieved outcomes (i.e., perceived value (DS-3) and longitudinal perceived value (DS-4)) may have varied, the codes present in Student C's responses across all four data sources are listed in the following table.

Table 51: Student Motivations, Goals, Perceived Value – Student C

STUDENT DESIRED OUTCOMES		**STUDENT ACHIEVED OUTCOMES**	
Motivations (DS-1)	Goals (DS-2)	Perceived Value (DS-3)	Perceived Value – Longitudinal (DS-4)
Product/project outcome—Th 4 Change outcome—Th 4	Course technology-specific knowledge and skills—Th 1 Problem-specific knowledge and skills—Th 1 Academic outcome—Th 4	Course technology-specific knowledge and skills—Th 1 Problem-specific knowledge and skills—Th 1 Teamwork/ interpersonal skills—Th 2 Design Thinking/ Human-Centered Design—Th 3 Type of work/project—Th 5	Discipline specific knowledge and skills—Th 1 Design Thinking/ Human-Centered Design—Th 3 Type of work/ project—Th 5 Type of organization/ team—Th 5

While sharing his career path since completing the course, Student C emphasized the importance of feeling proud and fulfilled in one's job, and the social responsibility to make an impact, if possible.

> So, you're going to spend eight to 10 hours a day doing something like a job. Right. And if you're not proud of what you're doing, you really need to start questioning why you're doing it. So, there's always difficulty in people's lives and circumstances where you need the money. And that's a completely valid point. Right. I completely agree with you. But if you're at a stage where you can think about making an impact, I think it eventually becomes a social responsibility to be like, all right, I've learned so much, I can do something. So, it's like you should do something about it. And if you feel proud about where you work, I think that's as fulfilling as it gets. And if you can do beyond that, that is on you, and that's even better. So, there's no right answer here, but if you can take pride in the work you do, and if you can find it fulfilling, and you can answer why I'm doing this, you're really set for life.

Student C highlighted how the course exposed him to different types of organizations and roles related to disaster response through the various guest speakers invited to speak to the class, including guest speakers from Loon and Google Maps, which contributed to his journey for career clarity (Theme 5).

> So, modern career paths, like, yes, the Google representative had a social designation to him. I don't remember the designation, but he was responsible for the disaster responses from Google. But it gave me a perspective that, all right, engineering can be taken into a disaster response site. Some companies do have positions that are particularly about disaster responses, and some companies themselves are only trying to address disaster responses. And that just opened possibilities. All right. It's not only the FANG companies or any hardware company that I can go to. There are many different companies that are trying to do direct impact to disaster response, like the NGO I talked about when the Turkey earthquake happened. There are people that are actually actively trying to address all these issues, and I don't need to conform to, or I really need to only work only for Apple or Tesla or whatever have you. I can work for different companies that are actually hands-on and, on the ground, when they're responding. And that was just a great perspective to have at that point. It opens up new career paths for you. If a lot of people really get impacted with different things and down the line, they really want to make a difference in that field. And a lot of times people don't understand that there is so much more to careers. Like, a designation is just a designation, but the projects that you'll actually work on will have a much greater impact, and you really need to find those things in these organizations.

4.6.3.4 Vignette 4: Student D (IDR3-Sp22, Female, Engineering, Graduate Student)

Student D was part of the 15-month Master of Development (MDevEng) program when she enrolled in Innovation in Disaster Response, Recovery, and Resilience in Spring 2022. Since completing the course in Spring 2022 and graduating from the MDevEng program in Fall 2022, she has been working as a digital transformation analyst for the United Nations Development Program (UNDP) to build innovative digital solutions for communities with limited resources. The post-course interview was conducted almost one year after completing the course.

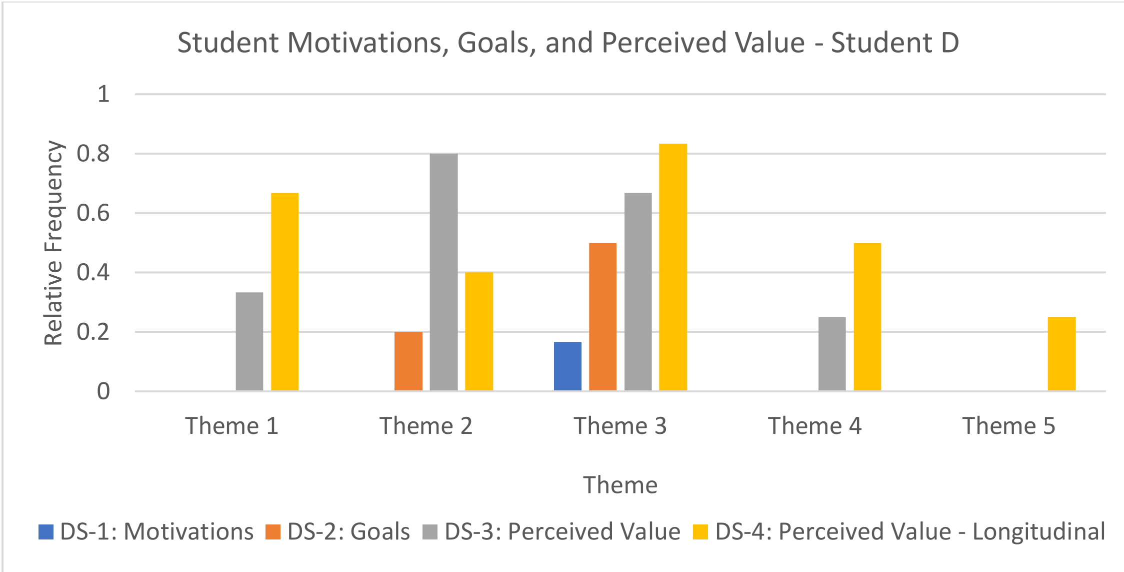


Figure 32: Student Motivations (DS-1), Goals (DS-2), Perceived Value (DS-3), Longitudinal Perceived Value (DS-4), by Theme - Student D

To understand how Student D's desired outcomes (i.e., motivations (DS-1) and goals (DS-2)) and achieved outcomes (i.e., perceived value (DS-3) and longitudinal perceived value (DS-4)) may have varied, the codes present in Student D's responses across all four data sources are listed in the following table.

Table 52: Student Motivations, Goals, Perceived Value – Student D

STUDENT DESIRED OUTCOMES		**STUDENT ACHIEVED OUTCOMES**	
Motivations (DS-1)	Goals (DS-2)	Perceived Value (DS-3)	Perceived Value – Longitudinal (DS-4)
Project management and leadership skills—Th 2 Frame and reframe problems—Th 3 Prototyping and experimentation—Th 3 Design Thinking/ Human-Centered Design—Th 4	Course technology-specific knowledge and skills—Th 1 Problem-specific knowledge and skills—Th 1 Academic outcome—Th 4	Course technology-specific knowledge and skills—Th 1 Teamwork/ interpersonal skills—Th 2 Communication skills—Th 2 Project management and leadership skills—Th 2 Client engagement/ relationship skills—Th 2	Discipline specific knowledge and skills—Th 1 Problem-specific knowledge and skills—Th 1 Communication skills—Th 2 Client engagement/ relationship skills—Th 2 Research, interviewing, and data collection—Th 3

		Research, interviewing, and data collection—Th 3 Frame and reframe problems—Th 3 Ideation and solution development—Th 3 Design Thinking/ Human-Centered Design—Th 3 Change outcome—Th 4	Frame and reframe problems—Th 3 Prototyping and experimentation— Th 3 Design Thinking/ Human-Centered Design—Th 3 Systems Thinking—Th 3 Academic outcome—Th 4 Professional outcome—Th 4 Type of work/ project—Th 5

While sharing her academic and professional career path since completing the course, Student D shared how participating in the course contributed to the achievement of academic outcomes (Theme 4) by continuing to work on the course project as her capstone project the following semester after completing the course. The course also supported the achievement of professional outcomes (Theme 4) in her role as the graduate student instructor for a class titled Disaster Lab. She then expresses how both these opportunities supported her journey for career clarity and better understand the type of role/project she would like to pursue (Theme 5).

> I never imagined that I would take this as my capstone project because I already had one project in my mind. But this project went so well, and I got so engaged in a positive way. It made me learn. I really got passionate about this project and the work that I did for this project. So, I thought that I might want to pursue this as my capstone. I wasn't very sure if it would be a successful one or not, but at least I should do something if I'm passionate about. So, I contacted the professor and asked if it is possible to take [the project] forward. And I did. And in parallel, I also saw this other course called Disaster Lab, where I can utilize all of these and be a Graduate Student Instructor. So, this really helped me understand the questions that I had in my mind. If I am really going to be, uh, is this the career path that I want to pursue in future? Or is this something that I would feel happy to do in my future? Or I'm not sure if I'm going to be good at it or bad at it. So far, I have been good at it. So, I would say this course was the beginning. It boosted me to pursue in the field of innovation and technology solutions; and bring solutions for the low-income communities or be a part of international development.

4.7 Limitations

4.7.1 Limitations in Coding

Qualitative research is inherently subjective as different coders can code the same response differently. The subjectivity of coding qualitative data was minimized though a rigorous multi-iteration inter-rater reliability testing that resulted in the refinement of the codebook. Additionally, multiple iterations of this testing and codebook refinement were conducted until interrater reliability reached nearly 95% and Cohen's Kappa values for all but two codes were at "near perfect agreement."

While multiple codes could be assigned to a 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 nuanced insights for longer student responses such as the final reflection and the post-course interviews.

4.7.2 Limitations in Data Sources

Limitations of the course applications to assess students' motivations (DS-1) arise from the possibility that student responses may potentially be biased since students need to apply and be "selected" to enroll in the course. Students may feel the need to tailor their motivation responses based on the course description available to increase likelihood of being selected to enroll. For example, a student may feel inclined to include "I am interested in learning more about AR/VR" if the course description explicitly mentions AR/VR as one of the tool kits offered in the course.

Limitations of the final reflections to assess students' perceived value at the conclusion of the course (DS-3) arise from the fact that the final reflections are due after the final showcase for the course. The end of the course can often be a time of relief, excitement, and sense of accomplishment from successfully completing the semester. Alternatively, students' concluding the semester with an unsuccessful project may negatively impact the final reflection; however, most student projects for the courses were successfully completed.

Limitations in the post-course interviews to assess students' perceived value one to three years after the course (DS-4) arise from the fact that although interview requests were sent to all students who enrolled in the course, interviews were conducted with a self-selected group of students who responded to the interviews request. Additionally, due to the increased time after the conclusion of the course, potential difficulty in reaching students from the earlier iterations of the course was an anticipated limitation. Although expected, this was not what was observed based on the sample of participants. Both the first iteration of the course (IDR-Sp20) and the last iteration of the course (IDR3-Sp22) had the most (equal) number of interviewees.

4.7.3 Limitations in Research Design

Although this research examines several years' worth of data, this data is in the context of only one course offering at one university without a control group to benchmark findings, limiting generalizability. This research intended to serve as an exploratory study into student's motivations, goals, and perceived value, including graduate students, a student population that has not been widely investigated. Based on preliminary exploratory findings, including differences between graduate and undergraduate students' perceived value, future research to incorporate a control group to investigate if initial differences surfaced in this study are unique to social-impact-driven, project-based design courses should be conducted. Suggestions on incorporating a control group are included in Section 5.2.

Chapter 5 Conclusions and Future Research

This research evaluates three years of a project-based engineering design course integrating a core PBSL element (social-impact driven projects), 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 one to three years after the PBSL experience, this research investigates how student motivation for engaging in PBSL aligns with the actual perceived value that students derive from PBSL experiences.

Students' motivations (DS-1) were captured from the course applications submitted before the semester began. Goals (DS-2) that students set for the semester and their project were collected through a goals survey completed at the beginning of the semester, after students' team and project assignments had been announced. Students' perceived value (DS-3) from the course was captured through self-reflections submitted at the conclusion of the semester. Additionally, semi-structured interviews with a sub-set of students were conducted one to three years after the conclusion of the course to explore students' longitudinal perceived value (DS-4) of participating in the course. Details about the social-impact-driven, project-based design course studied are provided in Section 3.2, details about the research participants are included in Section 3.3, and details about the data sources and data collection are outlined in Section 3.4. Student responses were coded for the following themes and codes shown in the table below.

Table 53: Summary of Coding Themes and Codes

Theme	Code
Theme 1: Develop/apply technical skill sets and content knowledge	Discipline-Specific Knowledge and Skills
	Course Technology-Specific Knowledge and Skill
	Problem-Specific Knowledge and Skills
Theme 2: Develop/apply professional skill sets	Teamwork / Interpersonal Skills
	Communication Skills
	Time Management Skills
	Project Management and Leadership Skills
	Client Engagement / Relationship Skills
Theme 3: Develop/apply design skills / processes	Research, Interviewing, and Data Collection
	Frame and Reframe Problem
	Ideation and Solution Development
	Prototyping and Experimentation
	Design Thinking / Human-Centered Design
	Systems Thinking
Theme 4: Achieve impact-oriented outcome	Product / Project Outcome
	Academic Outcome
	Professional Outcome
	Change Outcome
Theme 5:	Type of Role

Journey for career clarity	Type of Work / Project
	Type of Organization / Team
	Professional Values

The research questions investigated in this study included:

RQ1: What motivates students to enroll in social-impact-driven, project-based elective courses?
RQ2: What goals do students set for themselves when working on social-impact-driven, collaborative projects?
RQ3: What do students value from social-impact-driven, project-based learning opportunities?
RQ4: How do social-impact-driven, project-based opportunities influence students' perspectives on their future goals?
RQ5: How do students' desired and achieved outcomes evolve as they progress through social-impact-driven, project-based learning experiences?

5.1 Conclusions

Comparing students' desired outcomes—motivations (DS-1, n=70 course applications) and goals (DS-2, n=209 goal statements)—to their self-reported achieved/valued outcomes—perceived value (DS-3, n=68 reflections) and longitudinal perceived value (DS-4, n=12 interviews)—this research suggests that many students have a mismatch of value expectations from the course. More specifically, students are drawn to the social impact driven, project-based design course by the desire to solve problems but leave appreciating the *process* of design and problem solving.

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. Students' perceived value also indicated a substantial increase in the value of career clarity (Theme 5) resulting from participating in the course. Gaining career clarity was not a prominent theme in students' desired outcomes (motivations, goals), but increased in prominence in students' perceived value responses.

Although students leave the course with an appreciation or the skills they developed and outcomes achieved, often different from desired skills and outcomes reported in their motivations, understanding how this evolves as they progress through the course is important. Students' desired outcomes (motivations and goals) provide great insight in how to describe or "pitch" a course or learning opportunity to students. Understanding what motivates students can be valuable when developing course descriptions or disseminating other information about the course during the course recruitment and enrollment process. Students valued outcomes (perceived value and longitudinal perceived value), on the other hand, provide great insight for curricular development efforts. Understanding the learning outcomes students value and need can enable instructors to include opportunities to develop those skill sets throughout the course. While there may be some overlap between what student are motivated by, and what they value after the experience, this research shows this is not always the case.

5.1.1 The Development of Professional Skill Sets

With 85% of students reporting the opportunity to apply/develop professional skill sets as a valuable outcome at the conclusion of the semester, this work validated prior research indicating positive learning outcomes related to professional skill set development as a result of project-based service-learning, and experiential learning opportunities more generally. In post-course interviews conducted with students (N=12) conducted one to three years after the completion of the course, 67% of students continued to report the value of professional skill sets developed as a result of participating in the course. With a majority graduate student population, this research provided a unique comparison to the existing body of project-based service-learning research, which has mainly focused on undergraduate student groups to date.

Desired Outcomes: Motivations and Goals

Chi-square tests of independence showed that undergraduate students were more likely than graduate students to indicate motivations related to the application/development of professional skill sets (Theme 2), more generally. Additionally, within this theme, undergraduate students were more likely than graduate student to indicate the desire to develop/apply teamwork/interpersonal skills as a motivating factor to enroll in social-impact-driven, project-based design course. Finally, engineering students were more likely than non-engineering students to set goals related to the development/application of teamwork/interpersonal skills.

Valued/Achieved Outcomes: Perceived Value

Chi-square tests of independence showed that female students were more likely than male students to indicate the application/development of professional skillsets (Theme 2), more generally, as a perceived value of participating in the course. Additionally, 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 values of participating in the course.

While certain student populations were shown to be more likely to indicate motivations, set goals, or report perceived value related to the application/development of professional skill sets, the prevalence of this theme increased across all students with the progression through the social-impact-driven, project-based design experience. While only 28.6% of students indicated desired outcomes (motivations to enroll in the course) related to professional skill sets, 71.4% of students indicated desired outcomes (goals) related to professional skill sets when student goals were elicited after project and team assignments were announced. This increased desire to develop/apply professional skill sets could be due to students gaining a better understanding of the role the team component will play in their course experience. Finally, students increasingly reported achieved/valued outcomes related to professional skill sets with 85.3% of students indicating the application/development of professional skill sets as a perceived value of participating in the course.

The role of the team experiences in the successful outcomes of PBL and PBSL experiences has been documented. For example, Beckman et al. (2021) report that goal congruence, an aligned set of common goals for the team, result in higher team performance and better outcomes. Conversely, the difficulties of managing teamwork among students has been cited among potential barriers to the implementation of PBL and PBSL opportunities (Bani-Hani et al., 2018; Chaparro-Peláez et al., 2013; Jones et al., 2013). Faculty and instructors could benefit from scaffolding the development of teamwork/interpersonal skills with teaming strategies to support students in their desired outcomes to develop professional skill sets and improve overall team experience and learning outcomes for students.

5.1.2 Journey for Career Clarity

Students valued gaining career clarity—confirmation of pre-existing career paths, identification of new career paths, or a realization that a potential career path isn't of interest to pursue—all of which are valuable insights for students' regarding their future goals. While most students did not indicate gaining career clarity as a motivation to enroll in the course (only 13% cited career clarity), 63% of students indicated gaining career clarity—clarity on the type of role, type of work/project, or type of organization/team—regarding their future professional goals as valuable outcome of the course at the conclusion of the semester. Specifically, 53% of students indicated gaining clarity on the type of work/project they would like to pursue, with most indicating a desire to work on social-impact driven projects in their future work.

Many students cited clarity on the type of role/project they would like to pursue, often explaining that their participation in the course resulted in the realization of the possibility of career paths in social-impact-driven fields.

> One major thing that I would say that I learned is how my skill set can be used directly for humanitarian causes. That's something that I've never, ever thought of. I was always a person about I was an environmentalist. I used to go to these deforestation campaigns, forestation campaigns and beach cleanup campaigns. I was that guy. I was all about the environment. But humanitarian, it's a little bit more human centric. And that is where I learned my skill set can be directly useful

> to these disaster management type of scenario. (IDR-Sp20, male, engineering, graduate student)

Highlighting engineering as a field that can serve a broader societal impact, in contrast to a technology-centric view (National Research Council [NRC], 2009; Sochacka et al., 2014), 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" (National Academy of Engineering [NAE], 2005, p. 40) have been identified as needed changes to engineering education to improve retention in engineering.

5.1.3 Not all PBL Opportunities Are Created Equal - The Role of Social-Impact Driven Projects in PBL

The social-impact-driven, project-based design course included in this research has shown positive outcomes regarding the development of professional skill sets, an identified competency cap in new engineering graduates (Dym et al., 2005b; Eskandari et al., 2007; Lattuca et al., 2014). The course studied here is not unique in the ability to afford students the opportunity to develop and apply professional skill sets. However, unique characteristics of the course studied include the context and theme of the course resulting in disaster response related problem spaces selected for the course and the diverse student population (gender and discipline). Students did overwhelmingly cite the desire to achieve an impact-oriented change outcome, such as a working on large scale meaningful problems like climate change and more general altruistic motives, such as "creat[ing] something that can save human lives" and "do[ing] something good" as their motivation to enroll in the course. Additionally, students' responses valuing the development of professional skill sets and professional values commonly cited the value of working on diverse teams with diverse backgrounds and skill sets and the significant role diversity played in the success of their project.

Additionally, the social-impact-driven, project-based design course included in this research has also shown positive outcomes regarding students' career clarity and identification of professional pathways connecting engineering as a field with broader societal impact. Connecting the field of engineering to broader societal impact has been recommended to increase the recruitment and retention in engineering fields (National Academy of Engineering [NAE], 2005; National Research Council [NRC], 2009; Sochacka et al., 2014).

Not all PBL opportunities are created equal. The unique characteristics of social-impact-driven project in PBL show the potential to fill gaps in engineering education. Students' desire to work on meaningful, impactful projects are a strong motivator for students' participation in such courses and could also support the retention of students in the field of engineering.

5.1.4 Implications

5.1.4.1 Implications for Design Educators and Researchers

There are several interesting implications for design educators and researchers. For design researchers, this work contributes a longitudinal study of motivation and perceived value across a design driven PBSL course, offering new knowledge about the role and the evolution of motivation in driving student participation in STEM learning experiences and translation to perceived professional value. A longer, five-year longitudinal study is suggested to further investigate this evolution as students continue to progress in their professional careers could provide additional insight in students' longer term perceived value. This longitudinal study adds to the existing studies researching students' perceptions of value and how they evolve longitudinally previously conducted by researchers Cobb et al. (2008, 2016) and Lattuca et al. (2014), and supports finding previously reporting alumni valuing the development of professional skill sets in their professional careers.

5.1.4.2 Implications for Design Educators and Curriculum Developers

For design educators, this research suggests that many students have a mismatch of value expectations from the course. More specifically, students are drawn to PBSL for solving problems, but leave appreciating the *process* of design problem solving. Similarly, the career clarity provided by PBSL experiences appears transformative for several students, suggesting that design educators could build visibility for their PBSL programs and courses by emphasizing this aspect.

Additionally, students desired outcomes and values outcomes provide insight for design educators regarding the improvement of PBL and PBSL curriculum. Further exploration into strategies to employ to improve student experiences and promote the development of desired outcomes would be beneficial. Over the three offerings of the course studied the development of teamwork skills and the professional values were reported as positive outcomes by students and investigating strategies employed over the course offerings that may have contributed to students' positive experiences regarding teamwork could be valuable future research.

5.2 Recommendations and Future Research

5.2.1 Improved Design Study

This research focused on students' motivations, goals, and perceived value. Therefore, although students' motivation responses were collected from all students who applied to the course, only the responses from students who enrolled in the course were included in this study. Understanding why students who applied for the course but did not enroll in the course could also provide useful insights into students' motivations. There could be several non-course related reasons why a student who applied opted to not enroll that may not be captured in the course applications (such as a conflict in course schedule). Therefore, follow-up interviews with students who applied but did not enroll would be needed.

Further analysis of students' longitudinal perceived value through additional post-course interviews with a larger sample could provide additional insights. This research conducted 12 interviews with students and provided some insights into how students' perceived value changed between the time immediately following the end of the course to one to three years after the completion of the course. Future research should include additional semi-structured interviews or surveys with a larger sample.

Additionally, as briefly mentioned under the limitation of data sources, coding responses for frequency of a code within a response, not merely the existence of the code, could provide additional insight into relative value of each code.

Finally, since this initial exploratory study into students' motivations, goals, and perceived value found initial differences between various student population groups, future research should include a follow up study with a control group to determine if differences surfaced in this study are unique to social-impact-driven, project-based courses. Given some differences were noted between graduate and undergraduate students and this study was particularly interested in studying graduate student groups, a recommended control group would be another industry-facing capstone course part of the Master of Engineering (MEng) program, which does not have a social-impact-driven focus.

5.2.2 Curriculum Development/Refinement

The adoption and implementation of PBSL opportunities, and Project Based Learning (PBL) opportunities more broadly, does not come without challenges and barriers. Challenges hindering the implementation of PBL more widely include the high time investment on students' and faculty's parts in project management and knowledge application rather than knowledge acquisition (Noordin et al., 2011), challenges faced by faculty including difficulty in facilitating student teamwork (Bani-Hani et al., 2018), challenges faced by students including a lack of teamwork skills (Bani-Hani et al., 2018; Chaparro-Peláez et al., 2013) and a lack of learning motivation (De Camargo Ribeiro & Mizukami, 2005; Gratchev & Jeng, 2018).

Instructional elements related to project design, group experience, project advisor/sponsor in PBL opportunities affect students' overall experience in PBL engineering courses which can both foster and hinder and hinder student engagement (Jones et al., 2013). PBSL presents additional challenges and barriers to adoption as well. Recent work has suggested that the management of partnerships with service organizations can be difficult to sustain and scale to larger classes, that it is unclear how PBSL generally delivers value to partner organization, and that often service-learning courses prioritize student learning over community impact (Brubaker et al., 2022; Choudhary & Jesiek, 2016; Windschitl et al., 2007).

Considerations at the curriculum development level are required for successful PBL and PBSL opportunities. Recommendations for instructors and curriculum developers include the selection of projects and the scope of projects such that they are manageable within the constraints of a semester and the expected workload for students. Additionally, successful projects require the sustained engagement of project sponsors with student groups throughout the project, therefore expectations regarding the level of engagement required by sponsors should be clearly articulated. Additionally, design projects often require ample stakeholder interviews during the innovation cycle which means students ease of access to relevant stakeholders should also be a consideration during the project selection process. Finally, supporting students teaming efforts by providing tools and strategies for successful team formation should be incorporated into the curriculum to improve the likelihood of positive team experiences.

Future research should investigate the effect of different pedagogical strategies and curricular scaffolds to support students' PBSL experiences.

5.2.3 Supporting Career Clarity and Future Professional Pathways

Given the increase in students' perceived value of gaining career clarity, and the transformative experience for some, the inclusion of opportunities for students to learn more about potential professional pathways in social-impact fields could be beneficial. During a post-course interview, one student describes a transformative outcome of the course being the realization that their technical skills can be useful in a humanitarian way to help people. The student explicitly states that providing opportunities to pursue such career pathways would bring the transformative experience full circle.

> One major thing that I would say that I learned is how my skill set can be used directly for humanitarian causes. That's something that I've never, ever thought of. I was always a person about I was an environmentalist. I used to go to these deforestation campaigns, forestation campaigns and beach cleanup campaigns. I was that guy. I was all about the environment. But humanitarian, it's a little bit more human centric. And that is where I learned my skill set can be directly useful to these disaster management type of scenario. (…) I think what this course does is it identifies that. It identifies and it shows that, hey, this is how you guys can make yourself useful in a humanitarian way. But after the course, if it can show how to pursue that further as a career, that would be amazing. That just make it come whole circle. (IDR-Sp20, male, engineering, graduate student)

The same student continues to describe their desire to pursue a career pathway in disaster response/management and shares they actively searched for such opportunities but "failed."

> After taking the course, I really wanted to go into the disaster response or disaster management with first responders, like Red Cross. The UN also has a first responder team. I really wanted to do that. I really wanted to go into that field. I talked to people, but I was not able. I failed at that. I really wanted to go into that because it was sort of keeping on par with my interest in challenging myself every day and innovating talking to people. It's basically being able to solve a major problem. (IDR-Sp20, male, engineering, graduate student)

Finally at the conclusion of the post-course interview, when asked for suggestions to improve the course to better prepare students for their professional careers, this student suggests providing avenues for students to pursue potential career paths in related fields.

> I would say impact wise, structure wise, I don't think there's anything that can be changed [about the course]. But one thing I found hard was career. [The course] had an impact. And that impact now is diluted because I have forced to go into these other companies. Then I would say that if there are pathways for us in our careers where we can use these things directly, that would be just amazing because it would have made my job much easier. I'm okay if somebody tells me, oh, we have this role, but your skill set is not enough for it, it's okay. I might work on that; I might build it because I know I can. But now I don't even know what opportunities are out there. So, it did have a huge impact and I was really disappointed that I don't even know what I can do with that impact. I really want to help. I really want to go into that part, but I just didn't know how to pursue it. I talked to people, but that just wasn't successful. (IDR-Sp20, male, engineering, graduate student)

Many students cited clarity on the type of role/project they would like to pursue, often explaining that their participation in the course resulted in the realization of the possibility of career paths in social-impact-driven fields, like the student above. Reflecting on the difficulty the student above had pursuing their newfound interest, other students may have had similar experiences. Incorporating opportunities for students who may be interested in pursuing new career paths to learn more about actionable next steps may increase the impact and value the course provides students. Recommended opportunities include inviting guest speakers who are actively working social-impact fields to share their professional pathway with students or offering students the opportunity to follow up with guest speakers. Additional recommendations include selecting projects that would provide students with the possibility to continue work on the project beyond the conclusion of the course. For example, opportunities to continue the working on the project or opportunities to seek internship/employment opportunities and project sponsoring companies provide students with tangible next steps to seek and pursue new career paths. This type of partnership could also provide the service organizations with longer term value if it becomes a pipeline for new hires.

Future research opportunities include investigating the different curricular scaffolds and pedagogical approaches that support students' journey in career clarity. As discussed in Chapter 4, one course offering assigned a course activity guiding students through a self-reflective process about their future goals. Based on final reflections, students enjoyed completing the assignment and a few reported to be a transformative experience. While Career Clarity was most prevalent during that iteration of the course offering, career clarity was still prevalent in students' perceived value reported in subsequent course offerings as well.

Opportunities and courses, such as PBSL, are avenues for students to gain exposure and broaden their horizons life beyond college. A single course will not provide students with all the opportunities and exposure they need. The recommendations above provide suggestions for ways to increase the exposure that students could get from participating in such courses by including curricular scaffolds such as reflective assignment such as the "Design Your Life" activity in the Innovation for Disaster Response (Sp20) course, incorporating guest speakers who work in social-impact driven organizations to speak to the class about the work they do, arranging opportunities for students to meet with professionals working on social-impact driven projects to share their professional journey and path with students, and sharing any opportunities for students to continue working their projects beyond the completion, such as through internships with project sponsors.

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