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Work in Progress: Transforming Undergraduate Learning in the Pursuit of Innovation: Transdisciplinary Coursework and Its Influence on Entrepreneurial Thinking

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Transforming Undergraduate Learning in the Pursuit of Innovation:
Transdisciplinary Coursework and its Influence on Entrepreneurial Thinking
(Work in Progress)

Introduction

Universities have long played a crucial role in shaping society's responses to changing technologies, economies, and living environments. However, to continue to harness the nation's great technological potential, universities must seek to better prepare undergraduates for addressing complex, contemporary challenges in both innovative and transdisciplinary ways. To best meet society's needs, undergraduates should embrace the ability to build upon new ideas, processes, and ways of seeing things that add value to the world in a manner that emphasizes social and personal responsibility across fields of study. As the National Academy of Engineering [1] states, "innovative thinking should be an expectation of the university community and all students should be exposed to it early" (p. 6). Accordingly, multiple strategies have been enacted to attempt to engage students in innovation-focused learning, including engaging with design-based coursework in engineering settings [2] - [4] and providing learning experiences that emphasize entrepreneurial thinking [5] - [8]. While such initiatives strongly influence students, undergraduate learning continues to remain separated into individual silos, leaving students without access to authentic, transdisciplinary environments [9]. However, this paper highlights a recently developed transdisciplinary undergraduate education program focused on democratizing the practices of innovation across the broader college campus. Through this program students, regardless of their background or major, participate in co-teaching and co-learning from faculty and students in different academic units as they design, test, and optimize solutions to modern problems over multiple semesters. An examination of how the integration of these elements throughout multiple iterations of one component of the program will be presented along with its influence on students entrepreneurial thinking in regard to problem framing. These results will be positioned to better inform the development of similar educational programs as colleges and universities now have the responsibility to build a better future through the pandemic in novel and positive ways.

Research Question

This study investigates the influence of transdisciplinary innovation coursework related to student cognition for problem framing. The research question that guided this question was

> RQ. How does innovation-focused coursework that integrates technology, liberal arts, and business development through co-teaching and co-learning influence the way in which undergraduate students frame design problems in relationship to an entrepreneurial mindset.

Seeking the answer to this question can help to better understand the influence of transdisciplinary coursework, co-teaching, and co-learning on the way students from a variety of backgrounds perceive problems and inform the way that educators integrate entrepreneurial thinking into authentic and relevant undergraduate learning experiences.

Background

To collect and analyze the data necessary to answer this study's research question, a conceptual framework developed by [10] was used. This framework was developed based on the literature revolving around the cognitive operations for problem framing and entrepreneurial engineering mindsets to depict a) how individuals may react when encountering an ill-structured or complex problem as well as b) the way in which an entrepreneurial engineering mindset may influence this process. As such, the framework consists of two main components, 1) cognitive operations related to problem framing and 2) the related aspects of an entrepreneurial engineering mindset. First, the framework describes how the characteristics of an entrepreneurial engineering mindset may influence the way in which people perceive problems. This includes the characteristics of business acumen, understanding customer needs, understanding societal values, and technical depth. Second, the framework details five cognitive steps that one may take to analyze a design/problem scenario and formulate it into a problem statement. This includes perceiving the design scenario, activating prior problem representations, specifying problem representations, specifying representational factors, and reorganizing representational factors. These cognitive steps may also include paying attention to and perceiving the environmental cues surrounding the problem, being aware of cues associated with their own knowledge structures, evaluating activated representations of the problem scenario using set criteria that is influenced by their personal knowledge structures, acknowledging the key factors to extract from the problem representation, and reorganizing the representational factors to create a problem statement (See [10]). By leveraging this framework, this study seeks to expand upon their research in regard to the integration of entrepreneurial thinking and design/prototyping through co-teaching/co-learning and its influence on participants in relationship to perceiving and framing problems.

Methods

To answer this study's research question, data collected from six iterations of one course component of the transdisciplinary innovation program were analyzed. The coursework again focuses on integrating disciplinary expertise from technology, liberal arts, and business development through co-teaching and co-learning with an overarching goal of prototyping a solution to a problem as well as a related business model. The following sections will further detail the context of this coursework, the participants under investigation, the data collection methods, and the analysis techniques.

Context

This study revolves around understanding the influence that a novel transdisciplinary undergraduate minor degree program, focused on the practices of innovation, has on the way that learners frame problems and develop an entrepreneurial mindset. A core feature of this program is that courses are co-taught with faculty across colleges with expertise in design, anthropology, business development, entrepreneurship, and prototyping. Also, undergraduate students are then positioned to co-learn with a variety of students across different majors, which is situated to help bring the diversity of thought and capabilities to the innovation experience and better prepare students for the future of work. Co-learning occurs primarily within design teams, which are assigned by the instructors in the first core integrated course, and students decide their own groups in the second core integrated course. The program overall is designed to augment the way in which students learn across multiple semesters and plans-of-study rather than just serving as additional courses to add to their course load. Therefore, the program is designed to provide all students, regardless of their major, a multi-semester learning experience focused on the actual pursuit of innovation. By doing so, the goal is to afford students the space/flexibility to explore the practice of innovation and learn within the context of their own passions or innovation projects while they have access to campus support for technology commercialization and start-up ventures.

The learning sequence for the innovation-program consists of five elements. First, is a disciplinary-focused introductory innovation experience that leverages the expertise of different colleges to build an "on-ramp" to innovation. Second, is a unique set of two core integrated courses to augment the way in which students learn across multiple semesters whereas students learn specific design principles, research strategies, and business development practices in teams from varying fields. This is positioned to supply opportunities for development and growth of knowledge from each other, but also to create an authentic team environment composed of multiple people of varying backgrounds, knowledge structures, and general personalities. The last three elements include a global/cultural experience to bring new perspectives into their innovation practices, a specialization opportunity to dive deep into a skill set that may be necessary to move their ideas outside of the classroom, and connections to the campus community for supporting outcomes such as technology commercialization, protecting intellectual property, launching startups or non-profits, and engaging in scholarship around their interests.

This study looks to analyze the influence of the core integrated coursework that emphasizes designing innovative solutions to problems explicitly for people. The first course is co-taught by faculty from technology and anthropology and introduces students to ethnographic methods to better identify opportunities for innovation and to determine how to be conscious of their target market and the related problems/desires of their end-users when developing a solution. The second course seeks to further explore these identified innovation opportunities by adding in faculty with expertise in prototyping/design as well as business development/entrepreneurship. Students work in smaller teams to narrow in on the problem they are seeking to solve and go through an iterative process of prototyping in tandem with customer discovery and business model development. The goal is for students to then refine their ideas in effort to move their solutions outside of the classroom and transform them into something that could potentially have an impact on people. In regard to this study, the focus of the investigation is specifically centered on the second integrated learning experience. This is to better understand the potential influence that integrating prototyping/design with business development/entrepreneurial thinking has on the way students perceive and frame problem scenarios. The data for this study was collected from the second core integrated course because all students would have already participated in and completed the first course.

Participants

The data for this study were collected over four years consisting of six iterations of the integrated coursework, starting in the fall of 2017 through the spring of 2021. This includes data from 96 participants across 18 different majors ranging from sophomores to seniors. The complete participant information can be found in Tables I and II.

Table I. Participant Demographics by Iteration

	Total Students	Gender		Freshmen	Sophomore	Junior	Senior
		M	F				
Iteration 1 (Fall 2017)	9	5	4	0	0	1	8
Iteration 2 (Fall 2018)	5	2	3	0	0	1	4
Iteration 3 (Fall 2019)	20	11	9	0	0	1	19
Iteration 4 (Spring 2020)	18	12	6	0	1	6	11
Iteration 5 (Fall 2020)	16	14	2	0	0	4	12
Iteration 6 (Spring 2021)	28	16	12	0	2	2	24

Table II. Categories of Participant Majors by Iteration

	Iteration						
Major	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Anthropology	0	0	1	0	0	0	1
Biomedical Engineering	0	0	2	0	0	0	2
Computer/Network Information Technology	0	0	0	0	1	1	2
Electrical Engineering	0	0	0	0	0	1	1
Engineering Technology Majors	0	0	1	1	3	5	10
Engineering Technology Education	9	4	5	1	1	4	24
Human Resource Development	0	0	0	3	1	0	4
Organizational Leadership	0	0	8	9	7	14	38
Selling and Sales Management	0	0	0	1	0	0	1
Supply Chain Management	0	0	1	1	1	1	4
Systems Analysis and Design	0	0	0	1	0	0	1
Transdisciplinary Studies	0	1	2	0	2	0	5
User Experience Design	0	0	0	0	0	2	2
Virtual Product Integration	0	0	0	1	0	0	1

Data Collection

To answer the study's research question, data were collected using a pre- and post-problem framing activity created by [10]. This activity enables the collection of data related to how participants identify issues they find important when analyzing a given design scenario as well as how participants would identify clients and acknowledge their needs. The pre/post problem framing activity is a one-page scenario describing a design team situation. The description of the situation includes 1) existing products the team had developed, 2) a new product opportunity, and 3) an emerging technology. After reading the design scenario, participants are asked to frame the situation from the viewpoint of a member of the design team. This includes identifying design criteria and constraints, potential stakeholders and market segments, important information or research needs, and any other potential issues related to the situation. The participants are given 15 minutes to complete this task. Based on the conceptual framework discussed earlier, the items they identify can be considered the problem elements that the participants would then adapt into a problem statement. The participants in this study completed the pre-activity during the first lab meeting of the semester and then completed the post-activity during the last lab session. The design scenarios used for both pre- and post-activities were developed to be structurally similar but with a different context (such as differing industries, technologies, or product opportunities). As [10] cite, this can allow students to transfer their knowledge to a new context and while not being influenced by the way in which they responded previously. The same pre- and post-activities were used for each iteration of the course. For iteration six, only data from the pre-activity are included in this study.

Table III. Examples of Coded Design Elements from Participants

Code	Definition	Examples
Business	Procurement and production costs, target market segments, external stakeholders, and training for testing and manufacturing	How many laborers will be involved in the project; find a way to expand outside North America; look at competitors; find a knowledgeable team.
Customer	Target users' experience and needs, aesthetics and appeal, safety issues, and market price	What about people who are colorblind; user comfort before, during, and after using VR; what new features do customers want; age group targeted.
Social	Research on a broader context, accessibility to the product, and potential risks	Are the results consistent across different severities of ADHD; seen as ethical for those without mental illness: what is the inspiration story for the product; how many studies should you conduct and get peer reviewed to prove the solutions works?
Technical	Feasibility of mass production, potential conflicts with other elements, technical problems with new materials, and prototyping and testing	If it runs on batteries, can it last long enough to be effective; what are the materials being used and how much do they cost; will we need to innovate VR or just translate it across industries; headset size/comfort

Data Analysis

The participant responses to the pre/post activity, which included all of the important issues that each identified for each design scenario, were analyzed using a predetermined coding scheme from the study's conceptual framework. Accordingly, each issue was coded based on the four aspects of an entrepreneurial engineering mindset which included *Business, Customer, Social,* or *Technical.* Examples of responses coded into each of the four categories can be seen in Table 3. For each participant, the frequencies of each coded response were calculated and compared between the pre- and post-activities via radial charts. There were in total 1061 coded responses, each assessed by two independent coders to address reliability. Of these items there were only 59 instances of disagreement which resulted in a Cohen's Kappa value of 0.931 for the total analysis.

Findings

To better understand the how the transdisciplinary innovation-focused coursework influences the way in which undergraduate students frame design problems the participant responses to the pre/post problem framing activities were coded to determine shifts in the way they identify the important elements of the presented scenarios. First, the data were analyzed across all six iterations of the course. In the pre-activity, a total of 530 design elements were identified. On average, participants identified 6.08 design elements total, with 1.67 *Business* (27.4%), 0.92 *Customer* (15.24%), 0.3 *Social* (4.97%), and 3.19 *Technical* (52.4%) elements. In the post-activity, a total of 597 design elements were identified. On average, participants identified 7.68 design elements, with 2.44 *Business* (31.8%), 2.15 *Customer* (27.97%), 0.88 *Social* (11.49%), and 2.21 *Technical* (28.74%) elements. Comparing the pre- and post-activities across all iterations of the coursework, it reveals that on average, participants shifted from primarily considering *Technical* elements into *Business* and *Customer* elements, with *Social* elements having raised awareness. Figure 1 illustrates the number of each identified code, taken from the total number of responses over the six iterations. The radial scale in Figure 1 is incremented by 100, whereas later figures have their own scale dependent on the number of design elements identified from that iteration.

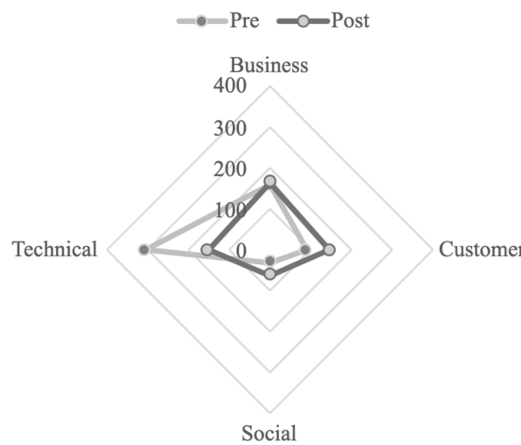

Fig. 1. Total Coded Responses Across all Iterations

Second, the data were analyzed between the different iterations of the course to show how the changes potentially occurred overtime as the full innovation-program was further developed. As seen in Figures A1 and A2 the first two iterations share a similar shift. The pre-activity for both iterations 1 and 2 shows that participants focused on the *Technical* elements of the scenario, while on the post-activity the participants shifted their focus primarily to the *Customer*-related elements of the problem (with a slight increase in the focus on the *Business* and *Social* elements of the scenario). Iterations 3 and 4 indicate a large shift in focus from the *Technical* elements of the problem scenario to an increased focus on the business, customer and social elements. See Figures A3 and A4. As seen in Figure A5, the majority of the problem elements identified by the participants in Iteration 5 were coded in the technical category. However, this is the first iteration where there was an increase in the elements identified between pre/post scenarios in all four categories

Discussion

Through the transdisciplinary innovation-focused coursework, participants experienced prototyping and business model development in a personally-relevant context. This was designed to help students develop an entrepreneurial mindset through co-teaching and co-learning across disciplines. Based on the conceptual framework developed by [10], it was assumed that by incorporating an entrepreneurial mindset into their existing knowledge structures, students would be able to focus on a wider variety of problem elements when participating in the post-activity. By comparing the pre- and post-activities, it was revealed that on average, participants' focus shifted from primarily *Technical* elements to *Business* and *Customer* elements after the course. This may be attributed to both the influence of the course project, as well as the development of the complete transdisciplinary innovation program. The noticeable differences between the first two iterations and the following three is that the participants were now completing the full sequence of the integrated coursework, that the first two iterations did not. Participants having learned previously about the importance of ethnography and designing for people, they appeared more prepared for identifying *Business* and *Customer* elements compared to previous participants that were focused mainly on *Technical* elements. The increase in majors represented in the program also may account for the increase in identifying *Business* and *Customer* elements. In the first two iterations, the entire course was comprised of technology majors, causing a potential lack of diverse thought. Iteration three began the process of expanding majors represented. This increase in representation and the illustrated shift of identified elements show a possible changing of perspective on what is important within problem framing for these participants. With the growth of the program, this shift is expected to continue as more participants from varying majors progress through the transdisciplinary minor after being exposed to the complete experience. This type of shift can be important as many tout that engineers and technologists must be able to acknowledge a customer's desires and the impact of their designs socially [11]. It should be noted that while an increase in these customer and business elements may be beneficial, it does not infer that reducing the focus on *Technical* elements is a positive outcome. Technical depth represents an important component of the entrepreneurial engineering mindset [12]. It should be noted that the limited time for both the pre- and post-activities (15 minutes) may not grant enough time for participants to consider all the details and thus, may miss some elements they normally would have recognized.

The transdisciplinary nature of the innovation program as well as the impact of co-teaching and co-learning may have also allowed shifts in the way in which the participants analyze and frame problems. For example, by engaging with peers of differing knowledge structures and backgrounds, the participants may find themselves in a setting similar to that of the professional world. Interacting and holding discussions about complex topics related to problem framing with these peers may grant an insight into perspectives that a student may previously have not considered when faced with a similar situation. Co-teaching may also enhance this experience by supplying highly-knowledgeable faculty that are able to intertwine and explain differing concepts in a way that allows clarity and connection. For example, when comparing pre- and post-activity shifts from one major to another, the data indicate minor differences between them. Figures B1, B2, and B3 each represent a different field of study—Technology, Organizational Leadership, and Engineering, respectively. All three participants increased their total number of important elements identified within the design scenario, with each representing a different shift. Technology and engineering students began by identifying *Technical* elements then shifted to *Social* and *Customer,* which were heavily discussed throughout the coursework. The leadership student showed more focus on *Business* and *Social* elements, understandably due to their educational experiences, before shifting to *Technical* elements that they would have learned throughout the coursework as well. These data may indicate that transdisciplinary innovation programs can push students out of their comfort zones into becoming more well-rounded innovators through the co-learning and co-teaching aspects.

Lastly, there are noticeable limitations that can be addressed. First, the data from this study was collected from a single course or snapshot within the innovation program. The analysis was, however, contextualized in this course with acknowledgements of the impact of the entire program. The second limitation is the problem framing activities developed for this study. Participants were asked to identify as many design elements as they could in 15 minutes, but this process does not mimic that of a natural design problem. This differs due to the process of framing problem spaces that co-evolve with the solution space during a traditional project [13]. Lastly, the design situations were carefully written and developed for this study to maintain similarities with course projects and to the participants' abilities to transfer their learning to a given context. Due to this, the scenarios are different and could affect the participants' problem framing.

This study is a work in progress and experimental. It is an attempt to understand the benefits of alternative teaching strategies and the impact on students' efficacy relating to innovative and entrepreneurial concepts. More research will be needed to identify opportunities and barriers in this area and how it can be developed further. Continued research could entail recreating this study in a different university setting, expanding the current strategy to include more participants, or adapting the study to examine how these specific design elements are recognized.

Conclusion

This study investigated a novel transdisciplinary program for undergraduate learners that focuses on the practices of innovation through co-teaching and co-learning and its influence on the way in which students frame design problems. Students participated in both prototyping and business model development activities relating to the innovation process that resulted in a shift of focus from technical aspects of a problem framing activity to more customer and business-oriented perspectives from before the coursework to after. This can be important as it is deemed important engineers and technologists to consider various issues such as customer desirability, social impact and business viability, not just those related to technical feasibility to achieve more appropriate technological innovation [11]. As such, transdisciplinary innovation-focused programs aimed to integrate these four elements can promote a shift in perspective from technical-centric to a more well-rounded alternative.

Acknowledgements

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Appendix A
Coded Responses by Iteration

Figure A1

Coded Responses for Iteration 1

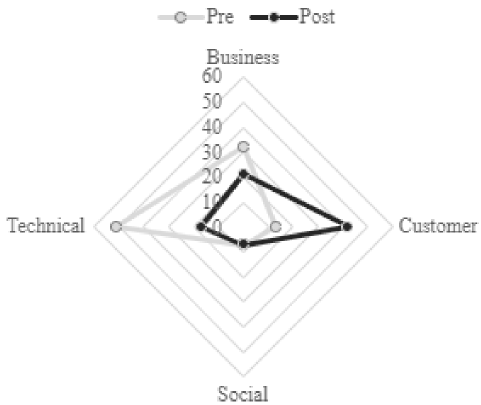


Figure A2

Coded Responses for Iteration 2

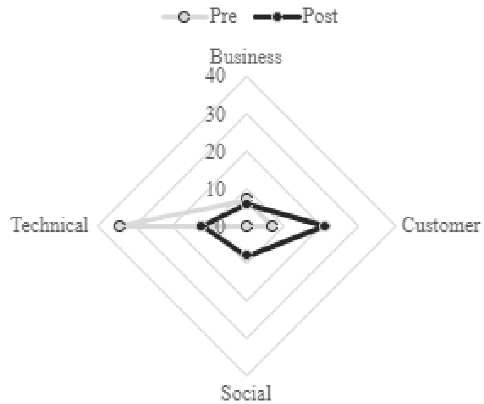


Figure A3

Coded Responses for Iteration 3

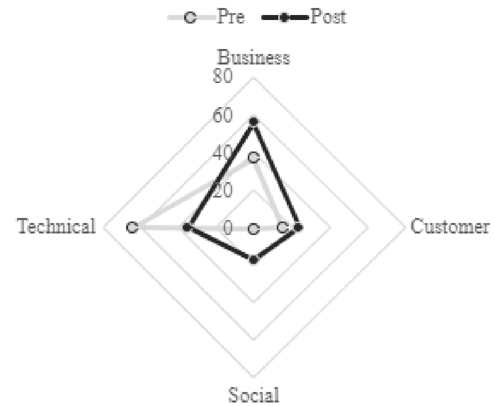


Figure A4

Coded Responses for Iteration 4

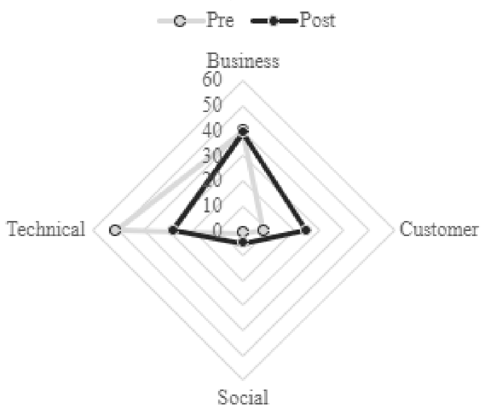


Figure A5

Coded Responses for Iteration 5

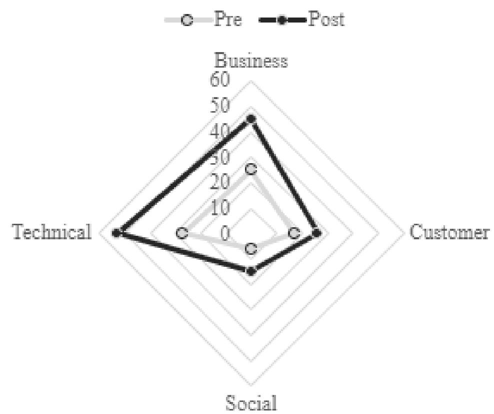
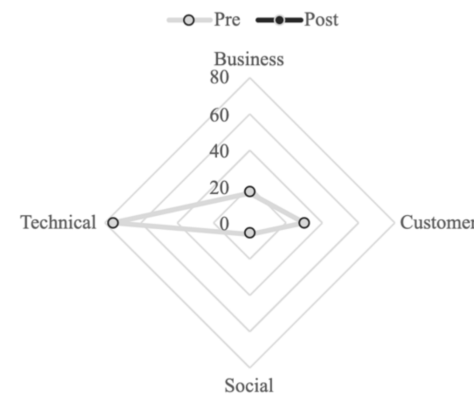


Figure A6

Coded Responses for Iteration 6



Appendix B
Student Shift Examples by Major

Figure B1

Technology Student Code Shift

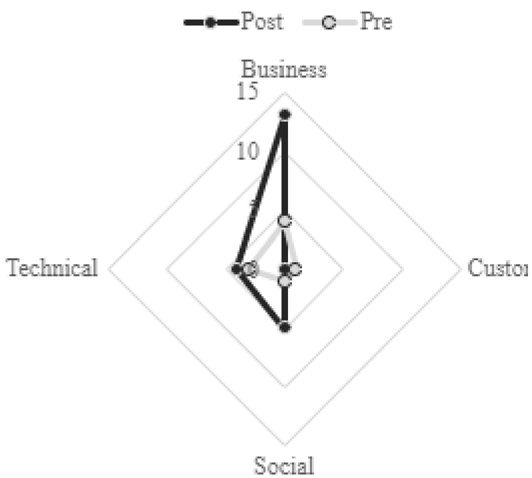


Figure B2

Organizational Leadership Student Code Shift

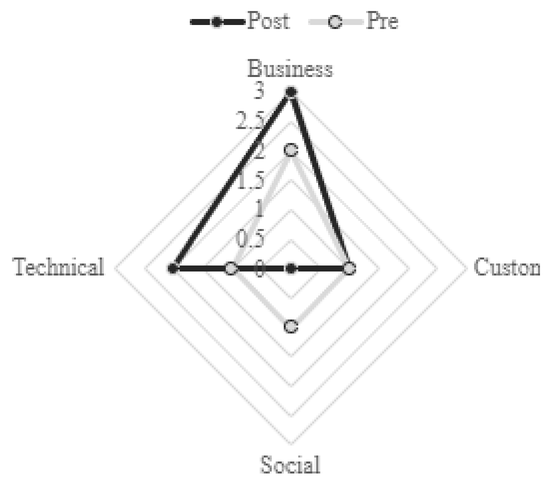


Figure B3

Engineering Student Code Shift