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# Human-Centered Design Framework and Engineering Student Entrepreneurial Mindset in a Restructured Materials Science and Engineering Capstone Course

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# Incorporating Human-Centered Design to Restructure a Materials Science and Engineering Capstone Course


## Abstract

Capstone design is the culmination of a learner's academic progress, where students utilize knowledge gained throughout the program's curriculum to complete a design project. Building on our previously reported work, this paper investigates students' reported ability and self-efficacy as it relates to a design framework and mindset in a restructured materials design capstone course. In AY 2022-23, a two-semester capstone sequence was piloted to improve the students' design experience via a fundamental restructuring of the course elements, replacing the traditional, one-semester course. In AY 2023-24, the two-semester sequence was formalized in the course catalog with over 50 students taking the two-course sequence.

In this restructuring, two frameworks were integrated in the course content: Human-Centered Design (HCD) framework, a method to formalize the design process in discrete stages, and the Engineering Student Entrepreneurial Mindset, a mindset to foster innovation through the lenses of curiosity, connections, and creating value (3 C's). The previous work utilized a case study approach on two capstone design teams in AY 2022-23; one team had the two-semester capstone sequence while the other had the traditional one-semester course. Based on these results, further innovation and research was conducted.

In the two-semester sequence, HCD elements and the 3 C's were introduced in the fall semester and revisited in the spring. The fall semester consisted of a mini-project to practice the framework in a low-stakes environment prior to the students receiving their capstone projects late in the fall semester. In the spring semester, students were to utilize the HCD framework and 3 C's to complete their capstone projects, with final deliverables of a poster and written report.

To investigate the uptake of students' perceptions, self-efficacy, and utilization of the HCD framework and the 3 C's, published surveys were conducted at the beginning of the fall semester, end of fall semester (midpoint of the sequence), and end of the spring semester, with 25 students (~42% of the class) completing all three surveys. These surveys tracked HCD elements as well as utilized the Engineering Student Entrepreneurial Mindset Assessment (ESEMA).

Analysis of the survey results show positive and statistically significant trends in students' reported ability and self-efficacy of all HCD elements, including to (i) conduct background research, (ii) empathize with stakeholders to identify underlying needs, (iii) resolve conflicting information from stakeholders, and (iv) define the goals of the design problem, among others. The ESEMA analysis shows a more nuanced trend, with empathy and ideation having a positive correlation over the three surveys but other elements (e.g., altruism) staying approximately the same and even one element (open mindedness) showing a negative correlation. Relating the ESEMA to the 3 C's shows a positive trend in the Creation of Value while Curiosity and

Connections staying relatively constant. The analysis provides insight and feedback on the courses' content, activities, and structure, allowing for evidence-based course modifications.

## Introduction

Capstone courses in engineering education denote critical milestones, with the overall goal to provide students opportunities to apply their understanding of the overall curriculum in real-world challenges [1, 2]. A key component to have a successful capstone experience is the ability of students to engage in both divergent and convergent thinking [3], as such, the overall curriculum must provide design learning experiences that provide students with the fundamental skills, knowledge, and opportunities to practice both divergent and convergent thinking. Oftentimes, these opportunities exist in explicit design courses. Additionally, design courses must engage students in design thinking processes, providing a framework for students to navigate and evaluate the complexity of design challenges. By doing so, this can lead to more innovative, creative, and inclusive designs, and such design may also increase productivity, improve quality, and minimize errors and development costs [4]. To provide students with the necessary tools to practice divergent and convergent thinking in design situations, one can integrate Human-Centered Design (HCD) into engineering capstone courses. However, integrating HCD into existing engineering courses is challenging; moreover, research studies indicate that the uptake of HCD processes by engineering students is complex and requires careful development and implementation of instructional strategies and course materials [5, 6].

Previous work highlighted the introduction of HCD into the course via a two-semester capstone sequence piloted in AY 2022-23 through a case study approach investigating two capstone design teams [7]. Replacing the traditional one-semester course with a two-semester sequence was a fundamental restructuring of the course. Along with this restructuring, HCD, a method to formalize the design process in discrete stages, and the Engineering Student Entrepreneurial Mindset, a mindset to foster innovation through the lenses of curiosity, connections, and creating value (3 C's), were formally introduced.

This work broadens the scope from two individual capstone teams to the class as a whole, investigating their self-reported ability and self-efficacy on HCD processes and the Engineering Student Entrepreneurial Mindset.

## Background/Theoretical Perspectives

*Capstone courses in engineering*

Engineering capstone courses are an important component in engineering education as they provide students with the opportunity to solve design challenges using their accumulated knowledge of their collegiate career. These design challenges are instructional, allowing students to practice and gain mastery prior to graduation. Oftentimes, these capstone experiences are senior design courses and serve as completion markers prior to graduation. These courses aim to provide the capstone experience through a multi-faceted "design" project [1], ideally incorporating real-world objectives and constraints [2]. Oftentimes, the design project requires students to balance several, at times competing, objectives. Aside from the technical feasibility of the design project, engineering students are also forced to consider business feasibility, environmental impacts, social, political, and ethical implications, manufacturability, and unintended consequences.

The design experience, where students are tasked to solve this design challenge, must be integrated with design learning, where students have the opportunity to learn and practice how to effectively design a solution that meets multiple objectives and constraints. Learning how to design is imperative for a successful design project, yet the teaching of design remains challenging [3]. Project-based learning (PBL), where teams of students are set upon a design project, has been extensively utilized in courses to motivate and engage students in this learning [8, 9, 10, 11].

A main challenge of design learning is the dichotomy of convergent and divergent thinking [3]. Broadly, the typical engineering curriculum focuses on convergent thinking, where a verifiable solution or outcome is expected from a given problem or question, e.g., will the beam fail with an applied load. Students grasp these solutions, as the answers are verified truth and are critical to understanding an engineering system. Design and design thinking are in the divergent thinking domain, where several alternative solutions and even possible unknown solutions exist. This requires thought to solution possibilities instead of verified solutions. These two diametrically opposite thought processes operate in two separate domains: convergent thinking in the knowledge domain and divergent thinking in the concept domain [3].

Both of these domains and types of thinking are necessary for a successful design experience, ultimately ending with a (hopefully successful) prototype solution. Past experience in the students' engineering curriculum prepares the students through numerous examples and engagements with convergent thinking, working to solve a particular problem with a particular solution. However, divergent thinking can pose significant challenges, requiring students tolerate ambiguity and think "what if". This is particularly challenging if an underlying framework is absent; a fundamental problem is that teams of learners, although tasked to "solve" or "innovate" in response to a particular challenge, do not have prior experience in designing new solutions, nor do they have a framework to guide them systematically [1, 3, 4, 12]. One possible solution is to integrate HCD into the curriculum and provide students with explicit instruction on HCD and its role in engineering, thus allowing and promoting utilization of the HCD framework that equips students with a flexible structure to navigate the design challenge [13].

*Integrating HCD in capstone courses*

As a problem-solving approach, HCD utilizes design thinking methods and tools to focus on the underlying design challenges, mainly understanding unmet needs of a population. Ultimately, this framework provides the tools necessary for teams to collaboratively and iteratively develop solutions. This is done through the deliberate HCD spaces that focus alternatively on diverging or converging thought processes [13, 14]. A key component of HCD is built on the principles of empathy and ideation. In this regard, solutions to design problems generated following the HCD framework are usually meaningful, relevant, and take into consideration factors such as economy, society, and environment [15]. To effectively create these solutions, the HCD processes emphasize empathizing with stakeholders and thoroughly understanding their perspectives. Oftentimes, this results in design teams receiving conflicting information; HCD expects this and provides a framework for design teams to collapse the information into relevant content. Once the stakeholders' perspectives are understood, the design team collaborates with the stakeholders to generate possible solutions through multiple iterations [14].

The HCD framework benefits the students by promoting situated learning, especially in engineering design projects, and facilitating students' growth in critical soft skills such as communication and collaboration [16]. In the technical design, the HCD framework generates improved engineering design solutions, including those that are more innovative, creative, and inclusive. Additionally, this approach has shown that design teams thinking more thoroughly through the entirety of the design solution, achieving solutions that increase productivity, improve quality, and minimize development costs and errors [4]. Given this, HCD cannot be separated from engineering design process nor viewed as an outcome of such; the HCD framework is critical to creating meaningful, impactful solutions. As such, HCD integration into existing engineering courses is being supported by higher education institutions [7, 16, 17, 18].

The integration of HCD into existing engineering courses has been the topic of several research studies highlighting mechanical engineering [17] and electrical engineering [18]. This integration utilized an evidence-based human-centered engineering design (HCED) framework. In this, HCD was incorporated into the engineering design processes with clear guidelines and a detailed framework that students can engage with, practice, and ultimately use within the context of their design project [16]. The five spaces of HCD are Understand, Synthesize, Ideate, Prototype, and Implement. Within these five spaces, further breakdown is achieved through subspaces that include understanding the challenge, building knowledge, weighing options and making decisions, generating ideas, prototyping, reflecting, and revising/iterating. It is shown that learning about HCD and implementing them in a design project within a semester-long course is complex and challenging [5, 7], with certain course elements, instructional models, and specific design project requirements hindering or fostering students' experience of HCD [6].

*The purpose of the study*

Previous work [7], using a case study approach [19] with two groups of students, suggested that teaching students in the Fall about HCD, its role in engineering, and the HCED framework is beneficial to their capstone project, completed in the following spring semester. In this study, we build on this framework. As the course curriculum has been formally changed, all seniors are now taking the fall and spring sequence. As such, obtaining survey data on students' perceptions and self-reported efficacy of the design process, along with the Engineering Student Entrepreneurial Mindset Assessment (ESEMA), can assist in course development and improvement.

Following previous work, key integration elements included providing students with explicit instruction on HCD and its role in engineering, an HCD framework that provides students with a flexible structure to navigate the design challenge [13], authentic, real-world design challenges with real clients, and reflection prompts to reflect and document progress on design challenges.

## Methods

*Design*

This study is part of a design-based project [20] that aims to revise the capstone course experience for material sciences and engineering students at a large midwestern university. In this study, a Qualtrics survey was administered at the beginning (late August), midpoint (early December), and end (early May) of the two-semester design sequence. The two main components of the survey are questions regarding the participant's confidence in HCD aligned tasks [21] as well as the ESEMA [22]. The HCD aligned questions, along with the survey results, are shown in Table 1. As reported in Pagano, et al., exploratory factor analysis was conducted to ensure internal consistency between the items per each of the HCD spaces [23]. ESEMA questions were used as previously published.

*Participants and Data Collection*

The surveys were conducted in academic year 2023-24 in the senior capstone sequence (fall-spring). The surveys were completed in a classroom setting with 60 materials science and engineering seniors. A total of 25 of the seniors (41.7%) completed all three surveys. During survey completion, the instructor and teaching assistants removed themselves from the classroom.

*Data Analysis Procedures*

To analyze the data, survey results were plotted as mean and standard deviation. Additionally, a Kruskal-Wallis ANOVA was utilized, along with Dunn's Test, to determine statistical significance of the responses in the HCD, ESEMA, and 3 C's categories. Both Kruskal-Wallis and Dunn's Test were set at a 0.05 significance level.

## Results

Table 1 shows the HCD aligned questions, along with the participants' mean and standard deviation. Of note, the questions did not have the HCD space, notated in the table in [brackets], during the survey administration. The survey asked the participants to rate their confidence using a Likert scale from 0 (low) to 100 (high) in increments of 10. In all HCD aligned questions, there is improvement of the mean from the presurvey to the postsurvey. Additionally, questions aside from Nos. 12, 13, 14, and 15 show an improvement from presurvey to midyear survey followed by more improvement to the postsurvey.

Collapsing these individual questions to the HCD spaces is shown in Figure 1. Using the Kruskal-Wallis ANOVA, the populations in each of the categories are significantly different. With Dunn's Test, all five spaces had a significant difference in the means comparing the presurvey to the midyear survey as well as comparing the presurvey to the postsurvey. Surprisingly, none of the spaces had significant statistical differences comparing the midyear survey to the post survey.

**Table 1.** HCD aligned questions on the survey, along with survey results. Note: HCD spaces (inserted in brackets) were not displayed to the participants. Survey used a Likert scale.

| **Rate your degree of confidence to perform the following tasks: 0 (low), 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 (high).** | **Presurvey** | **Midyear survey** | **Postsurvey** |
|---|---|---|---|
| 1. Conduct background research (e.g., internet research, market investigation) [Understand] | 80.0 ± 15.5 | 86.0 ± 15.8 | 89.2 ± 11.9 |
| 2. Empathize with stakeholders to identify underlying needs [Understand] | 64.4 ± 20.6 | 80.4 ± 19.9 | 81.6 ± 14.0 |
| 3. Resolve conflicting information from stakeholders [Understand] | 57.2 ±21.1 | 79.6 ± 12.4 | 81.2 ± 17.4 |
| 4. Define the goals of the design problem [Synthesize] | 77.6 ± 15.6 | 86.8 ± 14.6 | 90.0 ± 13.2 |
| 5. Identify trends/patterns in gathered information [Synthesize] | 73.2 ± 20.6 | 87.2 ± 11.4 | 88.4 ± 17.0 |
| 6. Frame design needs so that solutions can be developed [Synthesize] | 71.6 ± 19.7 | 82.8 ± 14.0 | 87.2 ± 18.6 |
| 7. Collaboratively generate design ideas [Ideate] | 80.8 ± 16.1 | 86.8 ± 14.6 | 89.6 ± 11.4 |
| 8. Generate a range of design ideas [Ideate] | 71.2 ± 17.9 | 85.6 ± 13.9 | 86.8 ± 14.6 |
| 9. Assess feasibility of design ideas [Ideate] | 69.6 ± 16.5 | 82.4 ± 14.5 | 86.4 ± 11.5 |
| 10. Create rough prototypes to get intermittent feedback [Prototype] | 64.8 ± 18.5 | 76.8 ± 12.2 | 84.4 ± 13.9 |
| 11. Select viable prototyping methods (e.g., physical prototyping, wireframing, simulations) [Prototype] | 52.0 ± 24.5 | 76.0 ± 15.8 | 80.4 ± 20.7 |
| 12. Iterate based on findings from prototyping [Prototype] | 68.0 ± 22.9 | 82.0 ± 12.6 | 82.0 ± 22.4 |
| 13. Clearly identify the purpose of creating prototypes [Prototype] | 76.4 ± 21.6 | 88.4 ± 11.4 | 87.6 ± 16.6 |
| 14. Create a plan for the implementation of a design solution [Implement] | 69.2 ± 22.9 | 83.2 ± 15.5 | 82.8 ± 18.6 |
| 15. Evaluate the effectiveness of an implemented design solution [Implement] | 70.8 ± 21.2 | 86.4 ± 11.5 | 86.4 ± 14.1 |
| 16. Communicate design solution to stakeholders [Implement] | 68.0 ± 19.1 | 84.0 ± 15.8 | 85.6 ± 14.7 |
| 17. Ensure the design solution continues to work in the future [Implement] | 65.6 ± 22.6 | 80.8 ± 17.1 | 82.8 ± 18.1 |

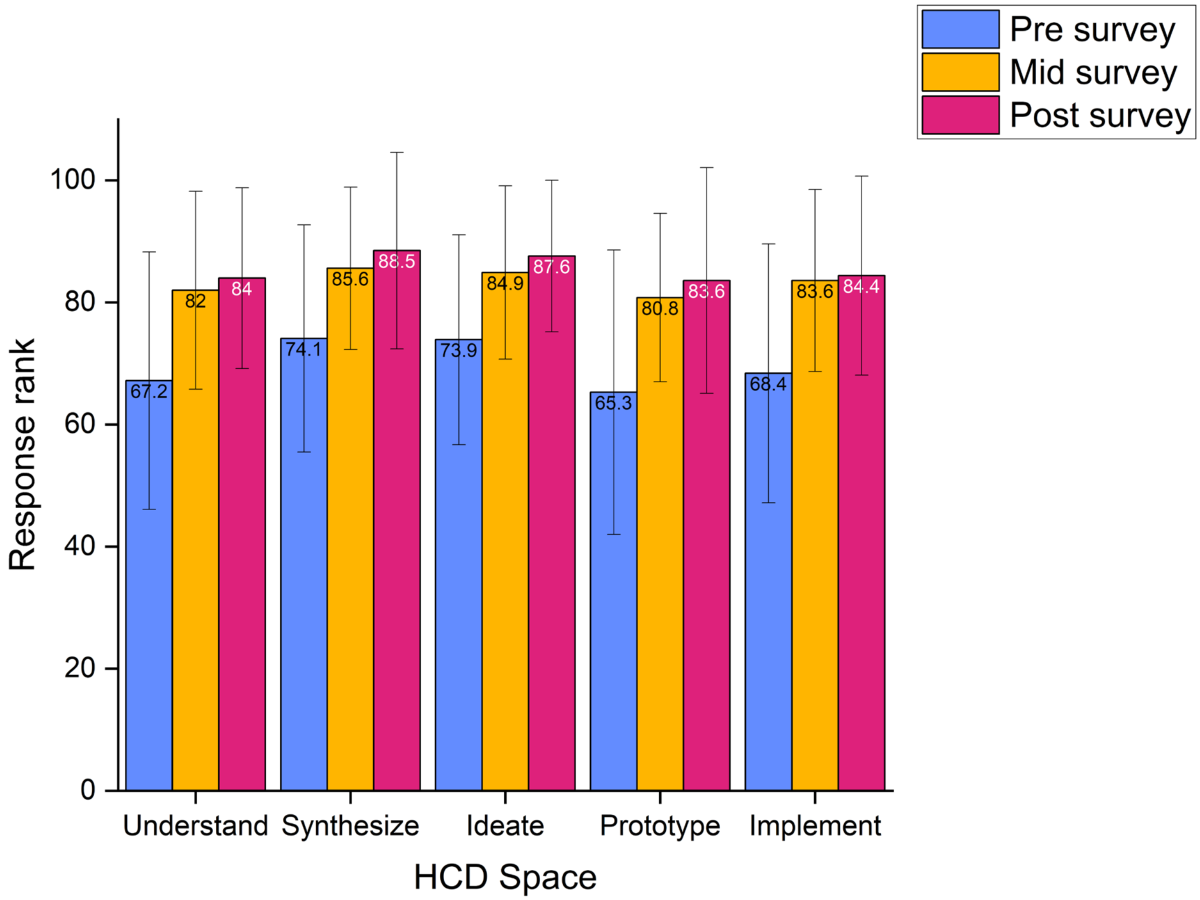


**Figure 1.** Survey results of HCD aligned questions, collapsed to their HCD Space.

The ESEMA utilized a Likert scale, with options of 1 ("never or only rarely true of me"), 2 ("sometimes true of me"), 3 ("true of me about half the time"), 4 ("frequently true of me"), and 5 ("always or almost always true of me"). These 34 questions were collapsed to their themes of Altruism, Empathy, Help Seeking, Ideation, Interest, and Open Mindedness, shown in Figure 2. Analyzing the data showed for Altruism, there is a significant difference between the midyear survey and the postsurvey only. For Empathy, the surveys were significantly different, as indicated from the Kruskal-Wallis ANOVA; however, Dunn's test did not show a statistically significant difference (the probability was 0.064 in relating the presurvey to the postsurvey, outside the 0.05 threshold). In Help Seeking, Kruskal-Wallis ANOVA showed no statistical differences in the survey results. Ideation follows the HCD trend, where there were statistical differences comparing the presurvey to the midyear survey as well as comparing the presurvey to the postsurvey; no statistical difference between the midyear survey and the postsurvey. For the ESEMA factor Interest, significant differences were found between the presurvey and the midyear survey as well as the midyear survey and the postsurvey. Of note, the midyear survey in the Interest factor shows a peak in results compared to both the presurvey and the postsurvey.

The last ESEMA factor of Open Mindedness did not show a statistical difference in the survey results.

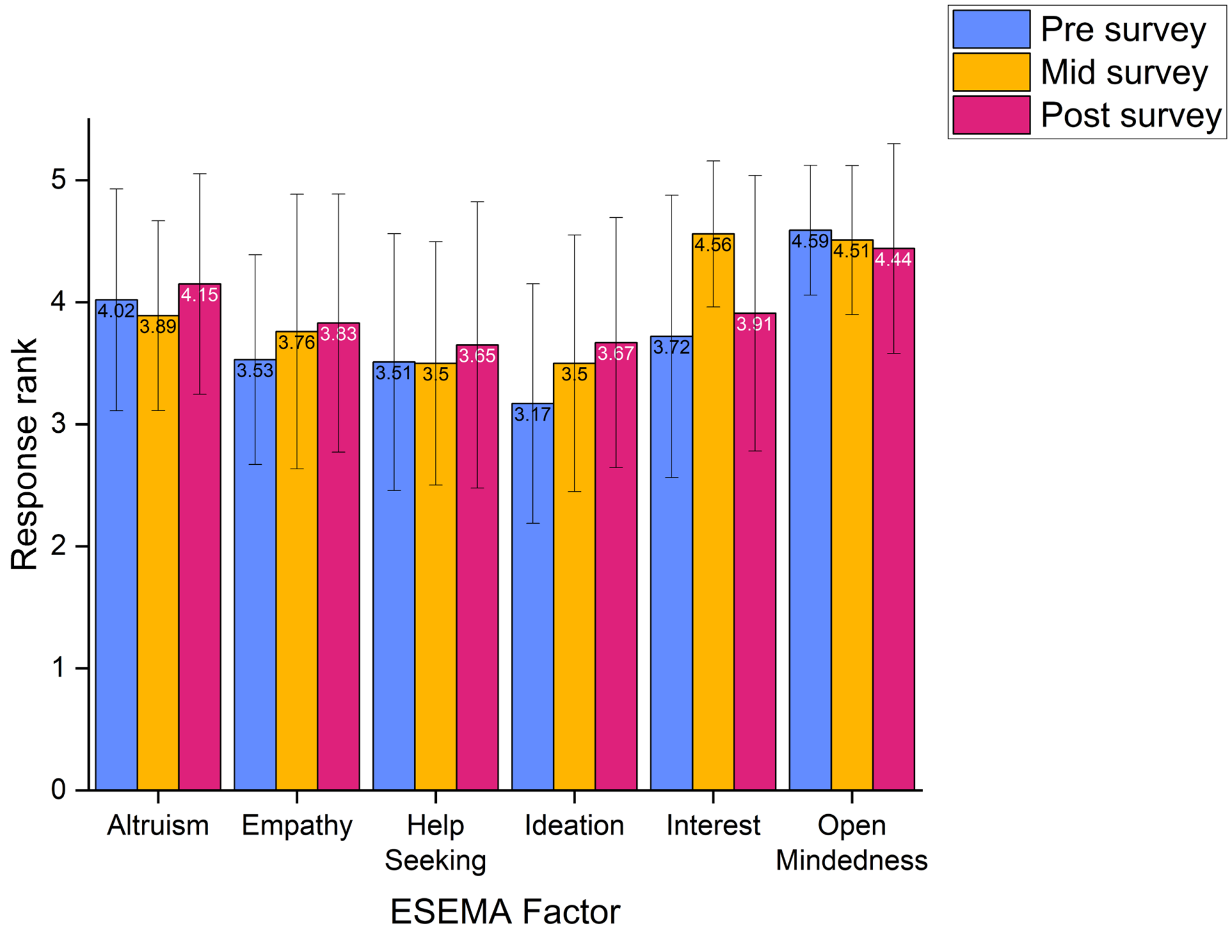


**Figure 2.** Survey responses corresponding to the ESEMA factor.

The ESEMA factors can be further correlated to the Kern Entrepreneurial Engineering Network (KEEN) 3 C's [22], as shown in Table 2, and the survey results shown in Figure 3. Statistical analysis shows that Curiosity has significant differences between the presurvey and the midyear survey as well as the midyear survey and the postsurvey. Of note, the midyear survey was statistically higher than both the presurvey and the postsurvey. Connections did not have any statistically significant differences among the surveys, however, Creation of Value had significant differences between presurvey to midyear, midyear to postsurvey, and presurvey to postsurvey. Creation of value was the only category to have a statistically significant difference among all three possible pairings of the surveys.

**Table 2.** Mapping ESEMA factor to 3 C's.

| Factor name | Correlation to 3 C's |
|---|---|
| Altruism | Creation of Value |
| Empathy | Curiosity |

| | |
|---|---|
| Help Seeking | Connections |
| Ideation | Creation of Value |
| Interest | Curiosity |
| Open Mindedness | Connections |

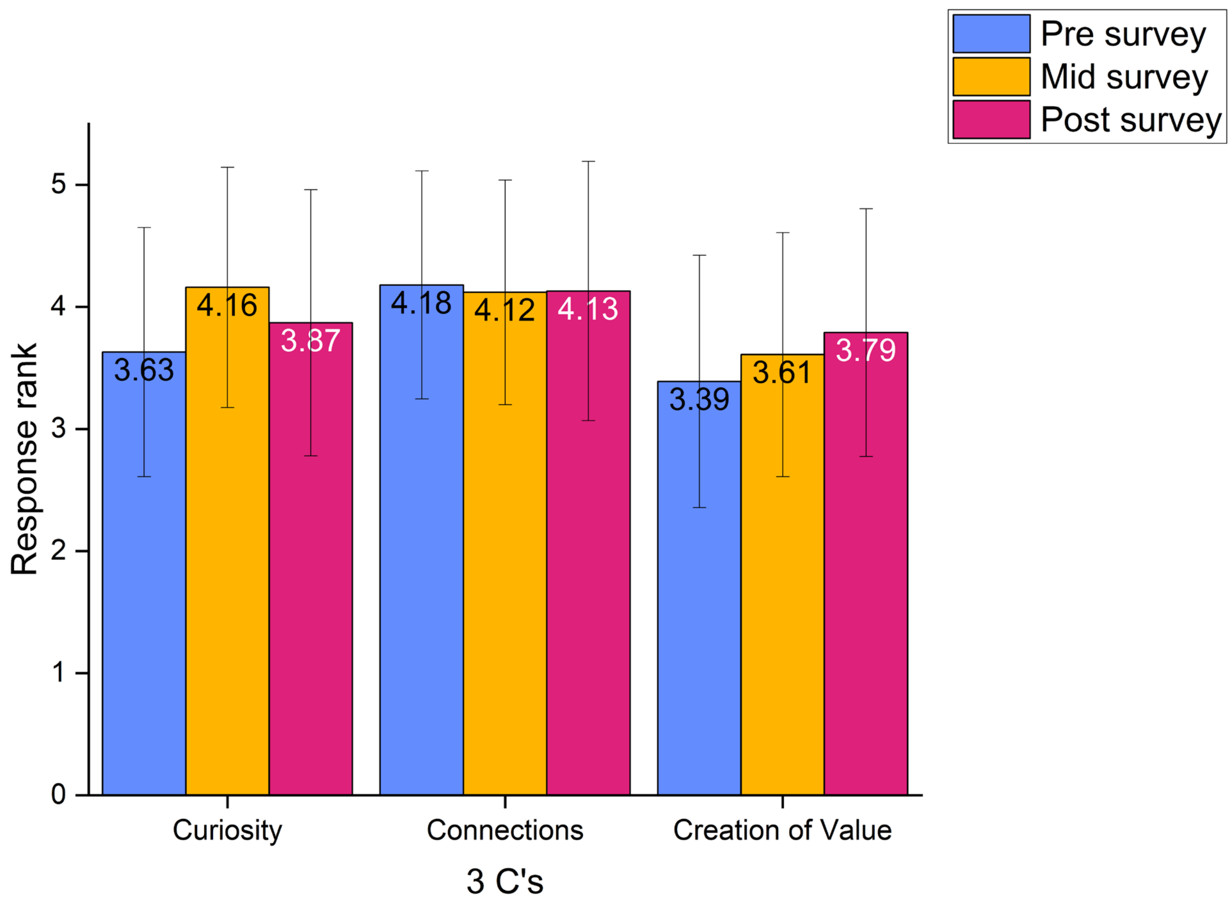


**Figure 3.** ESEMA survey questions collapsed to the 3 C's.

**Discussion**

The purpose of this study was to examine the students' self-reported ability and self-efficacy of HCD elements and their Engineering Student Entrepreneurial Mindset. By administering a survey at three points in the design sequence, namely at the beginning of fall semester, end of fall semester, and end of spring semester, snapshots can be obtained and correlated to classroom activities.

*Course Sequence Structure*

In academic year 2023-24, the materials science and engineer capstone experience was divided into two courses: a 1-credit, fall semester course, MSE 494 Materials Design Thinking, and a 2-credit, spring semester course, MSE 495 Materials Design. This sequence is required of all seniors in the materials science and engineering department for graduation. Exceptions were made for the few students away from campus in the fall semester on internship, study abroad, etc.; these students had an independent study course in the spring to fulfill their capstone sequence graduation requirement. In total, 60 students completed the materials engineering capstone sequence; 25 of these students completed all three surveys with these survey results used in this study (41.7% response rate).

In the 1-credit, fall course, class contact time was 50 minutes, once a week for the duration of the semester. Class time was spent outlining the topic of the day, typically an HCD space, followed by in-class, small-group activities that emphasized the topic. Approximately midway through the fall semester, a mini project was given to the class. In this, students self-selected into teams to solve a fictitious project: a neighbor wanted them to design a backyard shed. This project allowed students to practice the HCD principles in a design setting prior to their capstone project. Toward the end of the semester, students were given a list of capstone projects where they ranked their preferences and capstone teams were made accordingly. The final deliverable for the fall semester was a written literature review of the necessary background for their capstone project.

In the 2-credit, spring course, class contact time was 50 minutes, twice a week for the duration of the semester. Additionally, capstone teams were required to meet with the instructor or teaching assistant weekly for 30 minutes, providing an update on the progress of their specific project. Class time was spent highlighting HCD spaces, where the teams should ideally be, as well as other design considerations (e.g., business feasibility, environmental impacts of the chosen design, etc.). Major milestones in the spring semester included a midterm oral presentation to their peers, showcasing their proposed design solution, a final poster session, and a final written portfolio.

It should be noted that there was great intent to explicitly delineate the HCD spaces and provide examples and opportunities for the students to engage in each step. The fall semester course showcased all the HCD spaces with small group activities to highlight the specific HCD activities within each step. The spring semester had the students continuously reflect on what space their project was currently in and what steps the team needed to take to move the design forward. The Engineering Student Entrepreneurial Mindset, and by extension the 3 C's, were not explicitly nor overtly delineated in either course. Upon reflection by the team, this was an oversight and further iterations of the capstone sequence now integrate the mindset alongside the HCD spaces, allowing the students to engage with the mindset more explicitly.

*Interpretation of Survey Results, HCD Spaces*

The survey results show statistically significant positive trends in students' reported ability and self-efficacy of all HCD elements from the presurvey to the midyear survey. This correlates well to the course content of introducing the HCD spaces to the students in the fall course. It follows that a brief introduction of the HCD spaces, along with opportunities to practice the design elements in a low-stakes environment, significantly improves the students' reported ability and self-efficacy. This low-stakes environment of the mini project is believed to be critical in the students' development of the HCD design elements and their understanding and utilization of the HCD spaces.

The data also shows an increase in mean scores for all spaces between the midyear and postsurvey; however, these did not pass the 0.05 significance probability threshold. Further engagement with the HCD spaces allows the students continued practice of the design elements and may have a slight increase in their reported abilities. It is also probable that a one semester design project utilizing the HCD spaces is not enough to master the design elements; in fact, it may be the start of students' exploration in design where they realize mastery of design requires prolonged practice.

*Interpretation of Survey Results, ESEMA and 3 C's*

As noted previously, the Engineering Student Entrepreneurial Mindset, and by extension the 3 C's, were not explicitly nor overtly delineated in either course. Nevertheless, survey responses show some interesting results. In the ESEMA, Altruism had a significant difference in the midyear survey to the postsurvey. Note, the midyear survey mean was lower than the presurvey, and the presurvey to the postsurvey showed no statistically significant difference. Possible rationale relates to the end of fall semester deliverable, mainly the literature review. This report is not intended to highlight solutions or possible solutions; it is to provide background information and what has previously been done in the project space. In the spring semester, the final poster and portfolio are focusing on the design teams' solutions (along with alternatives). This focuses the students on solutions that benefit the client, leading to an increase in altruistic thinking.

Empathy and Help Seeking had no statistically significant differences and thus no conclusions can be drawn; however, it is encouraging to see an increase in mean scores. Ideation had significant differences between the presurvey and the midyear survey as well as the presurvey and the postsurvey. This aligns well with the HCD spaces as noted above. Interest is unique in that the mean was highest in the midyear survey; this is statistically significant difference between the midyear survey and the presurvey as well as the midyear survey and the postsurvey. One interpretation of this correlates the timing of the survey to the course activities. At the end of the fall semester, design teams had recently been given their capstone projects; it is thus not unlikely that the students will be excited about their new project and thus this excitement influences the students' reported results. After a semester of working on their project, at the end of the spring semester (and for most of them, end of their undergraduate career), their focus is perhaps narrowed to activities they deem necessary or most fulfilling.

Open mindedness had no statistical differences in the survey results; however, it should be noted that there is a slight decline in reported averages. This may be due to the natural completion of the project, where the students have converged on a solution in their specific design task and are thus reluctant for new information to be introduced.

Collapsing the ESEMA to the 3 C's shows interesting results. With Curiosity, the midyear survey was highest and had statistically significant differences between the midyear and the two other surveys. Correlating this to the course content, the peak in curiosity was soon after design teams were given their capstone projects. This corresponds to the ESEMA Interest result described above; new activities generate interest and thus curiosity. As the project continues, teams should move through the HCD spaces, ultimately converging on a particular solution. At each stage, a decision must be made to move the design project forward. While challenging existing solutions is important, to successfully complete a design project, the best solution at the given time should be taken, with further questions working adversely toward the design goal. Connections show an almost flat average across the three surveys with no statistically significant differences. Creation of Value has significant differences in a stepwise fashion, highlighting the importance of capstone design in engineering education. Engaging with the design process and working through their capstone project increased the students' activities that created value, with statistically significant differences between the presurvey to midyear survey, midyear survey to postsurvey, and presurvey to postsurvey.

**Conclusion**

Through surveys administered at the beginning, midpoint, and end of the two-semester capstone design sequence, it is shown that there is a statistically significant update of students' perceptions, self-efficacy, and utilization of the HCD framework between the presurvey and midyear survey. Data does show a positive trend between the midyear survey and the postsurvey; however, it is not statistically significant. This implies that introducing students to HCD processes through in-class activities and a low-stakes mini project prior to their capstone project provides the students with an opportunity to engage in the design process, focusing on both convergent and divergent thinking. These findings are supported by studies in other higher education contexts that show that novice designers need prolonged experiences in HCD processes to acquire fluency in applying these processes and integrating their outcomes [13]. This suggests that teaching students in the Fall about HCD, its role in engineering, and the HCED framework before they engage in the capstone project can be beneficial.

Survey results also find elements of the Engineering Student Entrepreneurial Mindset, while not explicitly delineated in the course, had a nuanced trend. The curiosity mindset peaked at the midyear survey, likely due to course elements at the end of the fall semester, including introduction of the students' capstone projects. Creation of Value had a statistically significant increase through all three surveys, showcasing the importance and impact of capstone projects.

It is to be noted that, while the results show a statistically significant difference in some areas, the study has several limitations. First, the findings have limited generalizability beyond this specific course given the small sample size and the differences in instructional design, student demographics, and institutional contexts in other courses. Second, self-reported survey data introduces the possibility of bias as students' understanding of the 3 C's and their assessment of the growth of these mindsets can be inaccurate. Third, the study did not include any qualitative data collection and analysis, such as interviews, which could have provided a deeper understanding of how and why students develop these mindsets over time.

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