Board 70: Redesigning a Capstone Course with Product Design in Mind: A Work in Progress

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After graduation, he worked in industry for 11 years at Priority Designs working on consumer goods, sporting equipment, lawn care equipment, medical devices, UI/UX development and marketing. In that time, Wisniewski was able to work with industry leaders like Nike, TaylorMade and Scotts. He returned to Ohio State because he missed teaching students. From his experience in his teaching assistant days, Wisniewski had the itch to get back in the classroom and help the next generation of engineers. His teaching goal are to give engineers a better understanding of manufacturing, visual communication skills, entrepreneurial endeavors and how to bring their ideas to life.

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Abstract
During summer of 2023, two capstone instructors in mechanical engineering at Ohio State University set about redesigning the capstone course to offer students an experience that would expose them to the world of product design and development, and infuse a design mindset to their engineering activities.

To redesign the course, the instructors participated in a "course design institute" through Ohio State University's Michael V. Drake Institute for Teaching and Learning in May of 2023. The month-long program let the instructors through the Backward Design Process. This process allows instructors to first identify desired student outcomes and then design the course around those desired results. It should be noted that this bears a striking resemblance to user-centered design, a core tenet of this capstone course, in which designers strive to first understand their stakeholders before designing a solution.

Employing the backward design process, the instructors first developed broad learning goals for the capstone course, which described what students would know how to do and what they would care about upon completing the two-semester capstone sequence. Next, the instructors identified learning outcomes, which describe what the students would be expected to know or formally do. This effort was followed by identifying assessment techniques and filling in the course's content.

Key aspects of the design mindset which were infused in this new course included: being inquisitive and open, being empathetic to others' needs, being accepting of ambiguity, questioning critically, and a proclivity to taking purposeful action.

The two instructors involved in this redesign both have experience in the industry of product design and development, and aimed to structure the course and project path to reflect many of the practices that designers and engineers might employ in the product development industry. Key practices that the instructors wanted to emphasize in the course included: research skills to gain understanding of stakeholders, contexts, and constraints relevant to a problem; a focus on problem finding & framing, rather than jumping right into a solution; developing divergent thinking to facilitate fluent and fruitful concept brainstorming; building communication skills beyond technical writing, to include visual communication and the importance of storytelling.

This paper will share a review of literature relevant to factors surrounding a design mindset and how a design mindset can impact design practice in the world of product development. Additionally, this paper will share benchmarking of best practices from the product design and development industry.

This paper will discuss the implementation of this new capstone course during the 2023-24 academic year. Future discussion will include:

- Summary of student outcomes
- Instructor reflection on implementation
- Comparison of standard course evaluations from the first course in the sequence (comparing previous iterations of the course vs. current iteration)
- Reflection from students on their experience with specific learning outcomes
- Reflection from students on the value and utility of certain exercises and skills

Background and Motivation for Work

The two instructors involved in this redesign both have experience in the world of product design and development, and aimed to structure the course in a way that would give students practice and exposure to the way that designers and engineers might manage a project in a commercial product development workplace. The instructors also hoped to infuse the course with a design mindset, the qualities of which have been defined as being inquisitive and open, being empathetic to others' needs, being accepting of ambiguity, questioning critically, and a proclivity to taking purposeful action. [1] [2]

This course redesign is a tale of two instructors. The first instructor, Annie Abell, is a career academic with an undergraduate degree in Mechanical Engineering and a graduate degree in Design Research and Development, which allowed her to develop expertise in user-centered design and research methodologies. She brings to the table proficiency in needs finding and front-end design techniques that allow designers to better understand the challenge and opportunity at hand. Key practices Abell wanted to emphasize in the course redesign were: integrating research techniques to better understand stakeholders, contexts, and constraints relevant to a problem; a focus on problem finding & framing to help students acclimate to working on ambiguous, open-ended problems; and an emphasis on creating solutions that are useful, useable, and desirable.

The second instructor, Dan Wisniewski, has undergraduate and graduate degrees in engineering, plus 12+ years of experience working at a product design consultancy and has only more recently moved to teaching. He brings to the table valuable experience from working as a design engineer on numerous projects for big-name clients such as Nike, American Standard, Electrolux, Midmark and many industries spanning from medical products, commercial solutions, home goods and front-end user interface design. His focus for this course redesign was to develop divergent thinking to facilitate fluent and fruitful concept brainstorming; building communication skills beyond technical writing, with emphasis on visual communication and storytelling. During Wisniewski's time in industry, he worked alongside incredibly talented industrial designers, which highlighted the importance of communication and visual representation of ideas when presenting one's design work. It also highlighted that engineers are typically not taught this set of communication skills that is so vital to success in the product design industry, so he is on a mission to infuse these skills into this capstone course.

The two instructors would each be teaching their own section of the Product Design Capstone in the upcoming academic year, but they wanted to work together to provide a consistent and cohesive experience across the two sections. Both instructors agreed that they wanted to design the capstone course so that it encouraged students to develop what they refer to as a 'design mindset'. Given that *design* is a widely used term that encompasses many overlapping disciplines (e.g., engineering, industrial design, architecture, fashion design, etc.), and therefore a 'design mindset' could mean different things to the people of those different disciplines, it is necessary to define the qualities that these instructors assigned to a design mindset. After all, as the noted design engineering educator Clive Dym wrote, "*Even 'design' faculty—those often segregated from 'analysis' faculty by the courses they teach—have trouble articulating this elusive creature called* design" [3].

The Design Mindset

Design is a natural human activity involving inquiry and action [4] and the inherent vagueness of this definition is perhaps the reason the activity of *design* has been adapted to be used in so many different disciplines. The qualities of inquiry and action are inherent in the field of engineering, so studying engineering naturally equips students with knowledge and skills to address technical challenges in the world and workplace. Diving further into etymology, there are various characterizations of what constitutes engineering, many of which approximate scoping, generating, evaluating, and realizing ideas [5].

The students in Ohio State University's mechanical engineering program participate in a rigorous curriculum that produces highly skilled and technically competent graduates. However, knowledge and skill alone are only part of the competencies needed for a designer to meet the ever-changing challenges in the world of product design [4] [6]. Even Gerhard Pahl (the author of renowned textbook *Engineering Design: A systematic approach*) has argued that the knowledge of technical systems is not sufficient to understand the thought processes that lead to successful design [3]. Missing is the component of mindset, which is the perspective that influences the ways that a person approaches and interacts with the world [4].

For our engineering graduates who want to succeed in the world of product design and development, they will benefit from the added perspective of a design mindset to their existing toolbox of technical knowledge and skill. Schweitz et al describe the qualities of a design mindset as being inquisitive and open, being empathetic to others' needs, being accepting of ambiguity, questioning critically, and a proclivity to taking purposeful action. Dym et al characterize some aspects of design thinking as the ability to "tolerate ambiguity that shows up in viewing design as inquiry or as an iterative loop of divergent-convergent thinking", "think and communicate in the several languages of design" and "handle uncertainty and make decisions" [3].

Process

These aforementioned qualities of a design mindset were the very qualities that the two instructors hoped to infuse in their capstone course. Developing a mindset is not something that can happen in one lesson, so it ended up being necessary for the instructors to interweave the qualities of a design mindset throughout the various materials of the course.

With this motivation in mind, the instructors set out to redesign the Product Design Capstone course sequence in the Mechanical Engineering program at OSU. The Product Design capstone is one of many options for mechanical engineering majors, with other options being General Capstone (industry projects), Motorsports Capstone, Assistive Devices Capstone, or Multidisciplinary Capstone. Given the many options available to students, the instructors have the leeway to specialize their course to the specific learning experiences that would benefit students looking to work in the product design industry.

Both instructors previously taught capstone courses, so they were able to identify the many opportunities to improve the delivery of Product Design Capstone to better reflect certain aspects of how projects work in the product design industry. Key opportunities observed by the instructors included:

- Moving away from prescriptive, task-based assignments, to allow students to take ownership over their project's direction and schedule, and moving towards a student-led focus on project planning and management;
- Emphasizing user-centered research and market research so students can gain a robust understanding of stakeholders to ensure they are creating a solution that fulfills a need and is what people will want;
- Emphasizing divergent inquiry to push students to fully explore problems and constraints, to lead to the creation of thoughtful concepts that are novel and innovative;
- Emphasizing the importance of visual communication and storytelling when presenting their work, which enhances overall communication, which in turn allows the project to progress more quickly

Progress to Date

To start this project journey, the instructors participated in a "Course Design Institute" through OSU's Michael V. Drake Institute for Teaching and Learning in May of 2023. The month-long program led the instructors through the Backward Design Process as developed by Wiggins and McTighe [7]. This process allows instructors to first identify desired student outcomes and then design the course around those desired results. It should be noted that the Backwards Design Process in education bears a striking resemblance to user-centered design, a core tenet of this capstone course, in which designers strive to first truly understand their stakeholders and the context of a problem before designing a solution.

Through facilitation of the Course Design Institute, the instructors worked through the following steps to build the new course.

1. Identify Big Rocks

Big Rocks represent the most important, essential elements and qualities of a course. (These elements are referred to as Big Rocks following the analogy that, to completely fill a container with rocks of all sizes, the big rocks must go in first, then smaller rocks can be added to fill in the cracks, and finally sand can be added to fill it up.) Identifying the big rocks in the first step helps instructors communicate the purpose of their course, whether to themselves or to others participating in the course design process.

To identify the Big Rocks for this product design capstone course, the instructors reflected on the prompts provided by the Course Design Institute, which are listed below along with the instructors' answers.

> *What things about the course and/or your teaching matter most to you? What would you be unwilling to give up?*
>
> - Emphasis on the user-centered Product design process
> - Development of visual communication / presentation skills
> - Development of project management skills
> - Reflection
> - Emphasis on tackling open-ended problems / divergent inquiry
> - Design Mindset

How do you want your students to be different after taking your course? What would you hope they would say about the course 5 years later?

- Students are more comfortable working with open ended problems
- Students are able to manage their own projects
- Students are able to break down / frame a design problem
- Students will always consider people in their future engineering solutions
- "I feel confident to apply the design process to any problem"
- "Capstone helped me develop critical thinking skills"
- "These skills helped me get ahead in my career"

What must happen for you to feel that the course has been successful?

- Students will develop innovative solutions
- Students will consider design constraints from multiple perspectives
- Students will be self-motivated to dive into ambiguous problems
- Project outcomes will consider usability as well as functionality
- Project outcomes will consider context & needs of users

What is it about this course that makes it your course?

- Industry experience of instructor / ability to present case studies
- Willing to be flexible & try new things on the fly during class
- Open-ended and autonomous format to the course

What is the heart and soul of this course?

- User-centered design
- Fun
- Collaboration
- Student autonomy (student-led projects, students are given the opportunity to learn and tackle ambiguous problems)

2. Course Goals

Next the instructors developed broad course goals, which describe what students would know how to do and what they would care about upon completing the two-semester capstone sequence. It should be noted that Goal E is a program-level goal which is mandatory to all capstone courses in all majors of the College of Engineering in order to fulfill requirements related to a newly-implemented general education program at OSU. Though the instructors did not come up with Goal E on their own, they believe it encompasses many essential elements they wished to include in their capstone course, such as self-directed student learning and autonomy. The complete list of course goals were as follows:

A. Students will use the design process as a tool to address user needs and create innovative solutions

B. Students will create design solutions that reflect an appropriate balance of internal and external constraints

C. Students will enhance or develop effective communication skills necessary for

success in the discipline of product development

D. Students will demonstrate agency as problem solvers when faced with ambiguous situations

E. Students will grow as a member of this class, a member of the engineering community, and as global citizens

3. Learning Outcomes

Next the instructors identified learning outcomes for each course goal. As many readers will know, learning outcomes describe what the students would be expected to know or formally demonstrate upon successful completion of the course. Below are the learning outcomes associated with each course goal:

A. Students will use the design process as a tool to address user needs and create innovative solutions.
   i. Understand the iterative and non-linear nature of design
   ii. Apply appropriate research methodologies to frame emerging needs for new product systems
   iii. Employ a range of idea generation techniques to develop numerous solution options for a given problem
   iv. Appropriately select solutions that meet business and end user requirements.
   v. Demonstrate a range of techniques for prototype development and testing
   vi. Provide constructive feedback in a collaborative team to ensure improved outcomes

B. Students will create design solutions that reflect an appropriate balance of internal and external constraints
   i. Evaluate the short-term and long-term impact of potential design decisions
   ii. Identify the functions, constraints, and specifications of a given solution
   iii. Identify stakeholders and understand their needs

C. Students will enhance or develop communication skills necessary for success in the discipline of product development
   i. Effectively communicate their design intent to a variety of audiences
   ii. Articulate the development journey and the impact of their work
   iii. Communicate concepts effectively through a variety of media and presentation styles
   iv. Demonstrate positive and effective communication while working within a team

D. Students will demonstrate agency as problem solvers when faced with ambiguous situations
    i. Acknowledge the known and unknowns
    ii. Proactively engage in research
    iii. Proactively gather resources, feedback, and/or mentorship
    iv. Develop a robust range of plans or options to address the situation
    v. Justify the choice(s) made to navigate the situation

E. Students will grow as a member of this class, a member of the engineering community, and as global citizens
    i. Consider public health, safety, and welfare as well as global, cultural, social, environmental, and economic factors in applying engineering design to produce solutions meeting specified needs.
    ii. Students individually assess and pursue personal professional growth in concert with project requirements and personal career goals.
    iii. Students develop an engineering mindset that demonstrates constant curiosity, makes connections between disparate bodies of information, and seeks opportunities to create value.

Approach to Developing Content & Assessments

Given that this was a redesign project, the instructors had a body of existing course material to use as a starting point for our new version of the course. Many existing lectures, lessons, activities, and assignments were used as a skeleton for the new course material. Keeping with the spirit of the backward design process outlined above, the instructors worked to revise, revamp, and rewrite course materials to connect back to student learning outcomes.

As context for the reader, an interesting feature of this Product Design Capstone course sequence is that students must be concurrently enrolled in a 3-credit hour Product Design Engineering elective during the first semester of the capstone sequence. This elective is designed to expose students to background, theory, and skillsets for approaching product design. The course is comprised of lectures, activities, and a project focused on design research and problem framing. This not only gives the students a more comprehensive and robust educational experience, but it also allows the capstone instructors freedom to structure the entire capstone course around the project, instead of having to spend time on content delivery about the design process.

The plan for the first semester of the newly designed capstone course can be seen in Table 1: Semester 1 Course Plan, along with a mapping of the course goals relevant to the activities in each week.

Table 1: Semester 1 Course Plan

	Topics /Assignments	Relevant Course Goals
Week 1	Preliminary project brainstorming (student led)	D, E
Week 2	Visual communication & Presentations	C
Week 3	Giving & Receiving Feedback, Dimensions of Teamwork, Project Topic Brainstorming	C, D, E
Week 4	Choose Project Teams, Make Research Plans	A, C, D, E
Week 5	Desk Research, User Research	A, B, C, D
Week 6	User Research, Status Report Meeting	A, B, C, D
Week 7	Formulate Problem Statements, Brainstorming	A, B, C, D
Week 8	Concept Ideation	A, B, C, D
Week 9	Concept Down-selection, Sketch Prototyping	A, B, C, D
Week 10	Project Management Techniques, Project Presentations	A, B, C, D, E
Week 11	Status Report Meeting, Prototyping	A, B, C, D,
Week 12	Shop Orientation	A, B, C, D,
Week 13	Prototyping	
Week 14	-Thanksgiving-	
Week 15	Final Presentations to Class	A, B, C, D, E
Week 16	Fall Design Showcase	A, C, E

The new project schedule and the associated assignments promoted divergent inquiry, student ownership of design direction, and the enhancement of project management skills. This started from the very get-go of the course, where the project topics were brainstormed by the class and with guidance and input from the instructors, students formed their own teams and choose their own project direction. As the project got underway, assignments were formulated in a way that gave support and guidelines but not explicit, closed-ended instructions for students. For example, when embarking on the research for their project, teams were asked to propose a research plan that would allow them to understand their stakeholders, the constraints on the design space, and the relevant market information. The students were not given explicit direction on things such as the sources to use, but rather they were asked to formulate the research plan and present it to the instructor, at which point they would receive feedback and advice on how to polish up their plans to gain a complete understanding of their topic.

As the semester got underway and students were deeper into tackling their design problems, the rhythm of the course turned to using class time as work time with instructors rotating through teams to get status updates. In this context, the status updates were brief 10–15-minute meetings where students could share progress and receive feedback and advice. The students were primed to be create brief, informal presentation materials for their status updates (such as a few presentation slides) to visually communicate their progress and prompt conversation and have a plan or agenda so that they could quickly and efficiently convey information with their instructor without shuffling around through multiple files on their computer.

The themes of autonomy and divergent inquiry baked into the open-ended course assignments were put there with the goal of getting students in the habit of taking purposeful action when meeting a challenge.

Autumn Semester Implementation

The instructors welcomed students to their classrooms for the autumn semester of the newly redesigned Product Design Capstone course. Professor Abell ended up with 6 project teams (30 students total) and Professor Wisniewski ended up with 7 project teams (36 students total). As the course material was rolled out from week one, the students were onboarded to the philosophy that the course would be structured to promote autonomy and student-led projects, which would require students to remain engaged with their project and work with a bias towards taking action.

This student-led engagement started from the first day, with project brainstorming. A menu of pre-planned projects was not presented to the class; rather the whole class (students and instructor alike) embarked on a brainstorming activity to come up with a list of possible projects that students could pursue. The instructors had some ideas they threw into the mix, but they were not promoted differently than those conceived by the students. The instructors acted as mentors during the project brainstorming to help the students scope projects appropriately and to make sure that the students were being set up for success. (Any reader who teaches capstone knows that a common occurrence is students optimistically biting off more than they can chew when proposing a potential project!). Leaning into the design mindset to embrace open-ended problems, the students were prompted to frame their proposed project topics as a question they would be investigating, rather than stating the design problem they would tackle. For example, instead of a project focused on “Design a new tool for dental hygienists” the project would be framed as “How might we improve the work of dental hygienists”, which opens many lanes of opportunity that the students might take. Because many of the project topics are quite novel or specific, not even the instructor knows exactly which lane the student team will end up taking or where the project will lead ultimately. This type of ambiguity proves to be challenging for capstone students to embrace, but a trusted technique is for the instructor to explicitly acknowledge the ambiguity to the students and let them know that though it is foggy up front, following the design process and doing research will lead to clarity [8].

Upon narrowing down the possible list of project topics to a reasonable amount, the students self-selected teams. (Self-selected capstone teams may sound to many like an invitation for chaos and unrest, but our instructors are, for better or for worse, prone to embracing organized chaos!) In both capstone sections, it only took a single class period to facilitate the self-selection process under the instructor’s guidance. During the selection process, students were encouraged to keep a flexible and open mindset and know that it was statistically unlikely that every single student would get their first-choice project. They were also *very strongly* cautioned by the instructor that choosing a group based on friends is a poor tactic—stories of woe from past capstone teams were shared as cautionary tales. Over the several years of capstone instruction, Professor Abell anecdotally observed that teams formed based on genuine student interest in the topic are MUCH

more likely to thrive than teams based on friendships. When all team members are interested and invested, it leads to better project outcomes.

Once all capstone teams and project topics had been settled, the students were asked to propose a research plan for their team. As described above in the 'approach' section of the paper, this assignment was in itself very open ended and encouraged students to engage in divergent inquiry and create the details of their research plan on their own. The guidelines of the assignment asked them to engage in desk research to understand the relevant background and situation surrounding their topic, as well as interactive user research (e.g., shadowing, interviews, observations) to gain an understanding of the relevant stakeholders, their context, and the constraints related to the design space.

Throughout the multi-week research phase of the project, students gave intermittent presentations of their work. The goals of these presentations were twofold: to help students practice their communication and presentation skills through giving project updates, and to give teams the opportunity to receive feedback from the class on their work to date. Sharing their work with the class allowed all students to see the details of the different projects happening in the course, which helped spark ideas and conversation between teams, and allowed all teams to benefit from the critical questioning and constructive feedback of their peers. A key aspect of the success of these feedback reviews was preparing to engage in feedback and equipping them with the knowledge to discern between useful feedback and un-useful comments, as well as the skills to receive feedback during a presentation. The students were prepped with a reading assignment and in-class discussion so that by the time the first presentations occurred, the students were of the right mindset to participate thoughtfully.

Once teams had worked through the research cycle and framed and appropriate design problem to tackle, the teams were prompted to brainstorm potential solutions. The teams were asked to come up with at least 100 concepts for their project, which the students considered to be an outlandish and unheard-of request. However, anyone who has been to design school knows that assignments with hundreds of concepts are what it takes to work through all possible ideas to come up with the good stuff. In this capstone class it was no different and the instructors took a cue from Linus Pauling's view on productive creativity: "the only way to have good ideas is to have a lot of ideas and throw away the bad ones!"

After moving through rounds of ideation, each team settled on a set of concepts to investigate via prototyping. The students were primed again for divergent inquiry and were encouraged to approach prototyping to answer a question and learn more about their design, rather than just building a physical object to meet a deadline. The assignments were set up to prompt students to make a prototype with a specific question about their design in mind. For example, a team might embark on a round of prototyping with the question "which position is best for the handle on our device?" and then build a few models with different handle positions to be able to evaluate their concepts in 3D.

At this point of the project, because of the varied nature of the project topics, teams started to stray away from being on one synchronized schedule. The instructors anticipated this given the

goals to have students take ownership of their project, so at this point assignments turned to be status report check ins which allowed each team to report on the issues and progress that was relevant to their own project. As previously mentioned, the status report meetings were meant to give the students a deadline by which to report out, but with the leeway to report on what was important and relevant to their own project path, thus reinforcing the independent project management and decision making that the students were to practice.

At the conclusion of the autumn semester, teams were at various stages of initial prototyping. Some teams were still investigating sketch prototypes, while other teams had moved on to, say, prototyping specific mechanisms of their design. The culminating events in the course were a final presentation to the class and a department showcase where students from many different capstone courses displayed their work-in-progress or their finished work (depending on whether they were in their first or second semester of the capstone sequence). The instructors of product design capstone used these final events as venues for the students to once again practice their presentation skills, with a PowerPoint-style presentation in class and a poster presentation for the department showcase. Since each presentation was a summary of work to date, the students were encouraged to really consider their audience and make secerning choices about how they presented their work to tell a compelling story that would clearly explain to the viewers that their product was meeting a real need in a novel way.

Initial Student Feedback

At the completion of the capstone course, students were given a reflection assignment in which they could rate how well the course helped them each of the course goals A-E, how well the course helped them achieve each learning objective, and to reflect on which aspects of the course were most influential in meeting the respective goals. The assignment asked them to evaluate on a scale of 1 to 5, where 1 was poor and 5 was excellent. Thirty-two of the 66 students completed the assignment, and an initial summary of the results are contained in Appendix A: Student Feedback Results.

Future Work

With the second semester second semester of the capstone course sequence wrapping up during the same week that this very paper was due, this work is being shared as a Work In Progress. The instructors plan to analyze the outcomes from this new course design, which they will report on in a full paper at a future conference. Future work will include:

- Complete survey results reporting summary of student experience and takeaways from the two-semester sequence
- Samples of reflection from students on their experience with specific learning outcomes
- Samples of reflection from students on the value and utility of certain exercises and skills
- Comparison of standard course evaluations relative to evaluations of previous iterations of the course
- Reflection from instructors on lessons learned

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Appendix A: Student Feedback Results

This appendix contains raw results from the student feedback gathered in an assignment at the end of the course sequence. Future work will analyze the outcomes. Thirty-two of the 66 students provided feedback for this assignment.

Students were first asked to rate how well the course helped them meet each of the course goals A-E. Next, they were asked to think about the outcomes associated with each goal and were asked how well how well the course helped them achieve each learning outcome. All ratings were on a scale of 1 to 5, where 1 was poor and 5 was excellent. Finally, students were asked to select from a list to identify which aspects of the course were most influential in meeting each course goal. The list of options from which they could choose included:

Open-ended project topic brainstorming activities
Process used for team formation
Research proposal assignment
Research assignments
Creating a self-directed project timeline
Class sessions dedicated as work time
Status update meetings with instructor
Concept Generation activities & assignments
Sketch prototyping activities & assignments
Meetings/communication with outside mentors (not course instructional staff)
Meetings/communication with outside stakeholders
Meetings/communication with teammates
Working/communicating with outside vendors
Communicating with the department finance team
Giving presentations to the class
Design Showcases
Orientation at Knowlton wood shop
Prototype Proposal Assignment
Prototype Evaluation
Fabrication and Prototyping Activities

Table 2: Summary of Ratings for Course Goals

Goal A: Students will use the design process as a tool to address user needs and create innovative solutions.	**4.77**
Goal B: Students will create design solutions that reflect an appropriate balance of internal and external constraints.	**4.62**
Goal C: Students will enhance or develop effective communication skills necessary for success in the discipline of product development .	**4.80**
Goal D: Students will demonstrate agency as problem solvers when faced with ambiguous situations.	**4.70**
Goal E: Students will grow as a member of this class, a member of the engineering community, and as global citizens.	**4.66**

Table 3: Summary of Ratings for Goal A and Associated Outcomes

Goal A

How well did the course help you meet Goal A? (1=poor; 5=excellent)	**4.77**
Understand the iterative and non-linear nature of design	**4.83**
Apply appropriate research methodologies to frame emerging needs for new product systems	**4.47**
Employ a range of idea generation techniques to develop numerous solution options for a given problem	**4.60**
Appropriately select solutions that meet business and end user requirements.	**4.59**
Demonstrate a range of techniques for prototype development and testing	**4.63**
Provide constructive feedback in a collaborative team to ensure improved outcomes	**4.67**

Table 4 Summary of Ratings for Goal B and Associated Outcomes

Goal B	
How well did the course help you meet Goal B? (1=poor; 5=excellent)	**4.62**
Evaluate the short-term and long-term impact of potential design decisions	**4.53**
Identify the functions, constraints, and specifications of a given solution	**4.63**
Identify stakeholders and understand their needs	**4.60**

Table 5: Summary of Ratings for Goal c and Associated Outcomes

Goal C	
How well did the course help you meet Goal C? (1=poor; 5=excellent)	4.80
Effectively communicate their design intent to a variety of audiences	4.80
Articulate the development journey and the impact of their work	4.70
Communicate concepts effectively through a variety of media and presentation styles	4.90
Demonstrate positive and effective communication while working within a team	4.83

Table 6: Summary of Ratings for Goal D and Associated Outcomes

Goal D	
How well did the course help you meet Goal D? (1=poor, 5=excellent)	**4.70**
Acknowledge the known and unknowns	**4.67**
Proactively engage in research	**4.53**
Proactively gather resources, feedback, and/or mentorship	**4.73**
Develop a robust range of plans or options to address the situation	**4.70**
Justify the choice(s) made to navigate the situation	**4.83**

Table 7: Summary of Ratings for Goal E and Associated Outcomes

Goal E

How well did the course help you meet Goal E? (1=poor; 5=excellent)	**4.66**
Consider public health, safety, and welfare as well as global, cultural, social, environmental, and economic factors in applying engineering design to produce solutions meeting specified needs.	**4.37**
Students individually assess and pursue personal professional growth in concert with project requirements and personal career goals.	**4.47**
Students develop an engineering mindset that demonstrates constant curiosity, makes connections between disparate bodies of information, and seeks opportunities to create value.	**4.83**

3. Which parts of the course helped you to meet Goal A? Select any that you think apply.
Goal A: Students will use the design process as a tool to address user needs and create innovative solutions.

More Details

Open-ended project topic brain...	27
Process used for team formation	12
Research proposal assignment	9
Research assignments	12
Creating a self-directed project ...	22
Class sessions dedicated as wor...	26
Status update meetings with ins...	18
Concept Generation activities &...	21
Sketch prototyping activities & ...	24
Meetings/communication with ...	12
Meetings/communication with ...	15
Meetings/communication with t...	25
Working/communicating with o...	7
Communicating with the depart...	2
Giving presentations to the class	9
Design Showcases	11
Orientation at Knowlton shop	9
Prototype Proposal Assignment	14
Prototype Evaluation	15
Fabrication and Prototyping Acti...	20
Other	2

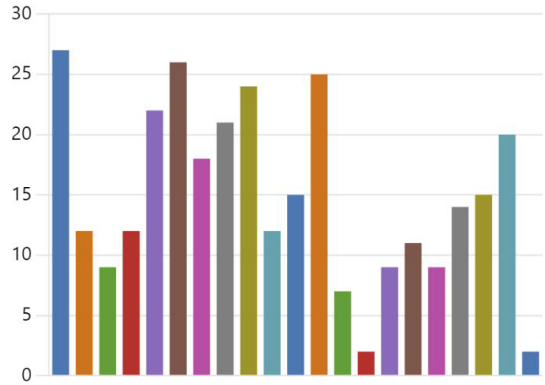

Figure 1: Student Responses on Course Elements Related to Goal A

6. Which parts of the course helped you to meet Goal B? Select any that you think apply.
Goal B: Students will create design solutions that reflect an appropriate balance of internal and external constraints.

More Details

Open-ended project topic brain...	16
Process used for team formation	2
Research proposal assignment	14
Research assignments	16
Creating a self-directed project ...	10
Class sessions dedicated as wor...	12
Status update meetings with ins...	14
Concept Generation activities &...	16
Sketch prototyping activities & ...	16
Meetings/communication with ...	16
Meetings/communication with ...	15
Meetings/communication with t...	16
Working/communicating with o...	13
Communicating with the depart...	6
Giving presentations to the class	12
Design Showcases	4
Orientation at Knowlton shop	1
Prototype Proposal Assignment	8
Prototype Evaluation	10
Fabrication and Prototyping Acti...	9
Other	0

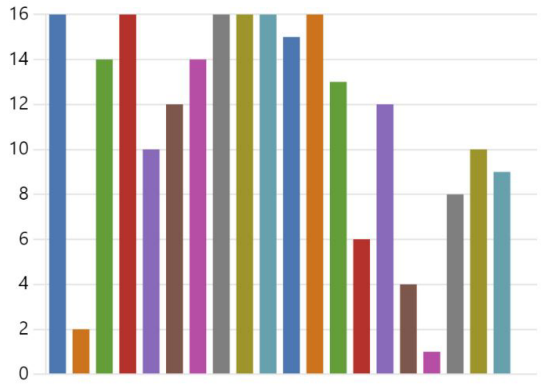

Figure 2: Student Responses on Course Elements Related to Goal B

9. Which parts of the course helped you to meet Goal C? Select any that you think apply.
Goal C: Students will enhance or develop effective communication skills necessary for success in the discipline of product development.

More Details

Open-ended project topic brain...	9
Process used for team formation	6
Research proposal assignment	4
Research assignments	2
Creating a self-directed project ...	9
Class sessions dedicated as wor...	10
Status update meetings with ins...	25
Concept Generation activities &...	3
Sketch prototyping activities & ...	2
Meetings/communication with ...	18
Meetings/communication with ...	20
Meetings/communication with t...	28
Working/communicating with o...	15
Communicating with the depart...	10
Giving presentations to the class	23
Design Showcases	15
Orientation at Knowlton shop	1
Prototype Proposal Assignment	3
Prototype Evaluation	6
Fabrication and Prototyping Acti...	3
Other	0

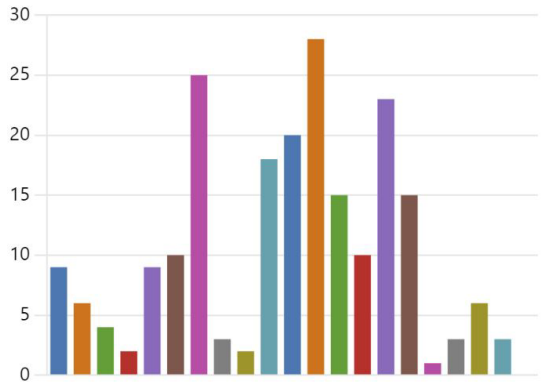

Figure 3: Student Responses on Course Elements Related to Goal C

12. Which parts of the course helped you to meet Goal D? Select any that you think apply.
Goal D: Students will demonstrate agency as problem solvers when faced with ambiguous situations.

More Details

Open-ended project topic brain...	21
Process used for team formation	6
Research proposal assignment	14
Research assignments	13
Creating a self-directed project ...	12
Class sessions dedicated as wor...	20
Status update meetings with ins...	15
Concept Generation activities &...	19
Sketch prototyping activities & ...	17
Meetings/communication with ...	10
Meetings/communication with ...	11
Meetings/communication with t...	18
Working/communicating with o...	8
Communicating with the depart...	2
Giving presentations to the class	7
Design Showcases	4
Orientation at Knowlton shop	2
Prototype Proposal Assignment	9
Prototype Evaluation	11
Fabrication and Prototyping Acti...	12
Other	0

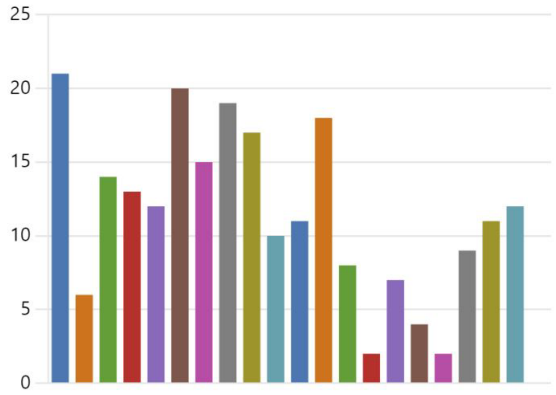

Figure 4: Student Responses on Course Elements Related to Goal D

15. Which parts of the course helped you to meet Goal E? Select any that you think apply.
Goal E: Students will grow as a member of this class, a member of the engineering community, and as global citizens.

More Details

Open-ended project topic brain...	13
Process used for team formation	8
Research proposal assignment	10
Research assignments	14
Creating a self-directed project ...	9
Class sessions dedicated as wor...	9
Status update meetings with ins...	15
Concept Generation activities &...	12
Sketch prototyping activities & ...	11
Meetings/communication with ...	13
Meetings/communication with ...	14
Meetings/communication with t...	20
Working/communicating with o...	13
Communicating with the depart...	8
Giving presentations to the class	21
Design Showcases	18
Orientation at Knowlton shop	3
Prototype Proposal Assignment	7
Prototype Evaluation	13
Fabrication and Prototyping Acti...	11
Other	0

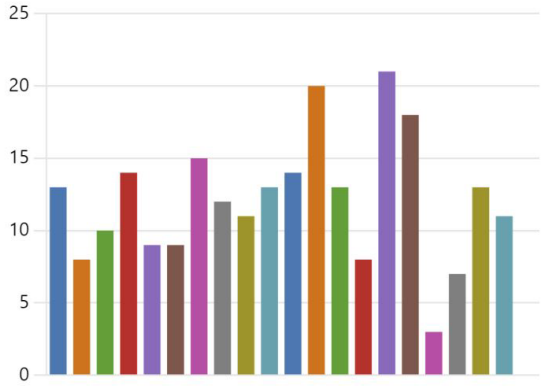

Figure 5: Student Responses on Course Elements Related to Goa E