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Introducing the Engineering Design Process to First-Year Students with a Project Focused on Offshore Wind Energy

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Abstract

This is a complete evidence-based practice paper. In 2019, a new semester-long course project was developed for our university's first-year engineering program that aimed to introduce students to the engineering design process (EDP) in an engaging and relevant way. Students in our small undergraduate-only engineering program earn Bachelors of Science degrees in Engineering, with a specialization in civil, computer, electrical, environmental, mechanical, or a custom area. Offshore wind energy was chosen as the project topic both for its relevance to the university's coastal location and because it touches upon many of the subareas of engineering that students can specialize in. To meet the additional goals of strengthening teamwork and project management skills, the team-based project was organized into a series of phases and milestones. During the first phase, students focus on project management and team-building by developing a Team Working Agreement. Phase 2 introduces students to the electrical and mechanical engineering applications of the offshore wind industry, where they apply the EDP to create blades for model scale wind turbines. The phase culminates in a class-wide competition to see which team can produce the most power. In the final phase, civil and environmental engineering applications are introduced. Students again follow the EDP, but this time the focus is on designing towers and floating platforms for their model turbines, to be tested for stability in a small water basin. Additionally, students assess the environmental sustainability of their chosen materials and design. The competitive nature of phases 2 and 3 seeks to motivate students to engage deeply with the work. In the Fall 2023 semester the project was implemented for the fourth consecutive time. This paper explores the efficacy of the most recent offering of the semester-long project in meeting the course learning outcomes, including fluency with the EDP, understanding professional skills, developing team-working skills, documenting designs, and introducing multiple subfields of engineering. Assessment is carried out by investigating student work as well as end-of-semester course surveys. The paper shares lessons learned and provides suggestions for future implementations.

Introduction

The variety and evolution of first-year design courses in engineering programs can be understood in the context of one of the skills they teach: the engineering design process (EDP). Such courses are a solution to the open-ended problem of teaching students how to do design. Some goals of the open-ended problem are self-consistent (the course should be exciting, engaging, and retain students), while others are somewhat at odds with each other (each student should learn how to do design, but also learn how to work in a team). Furthermore, each possible solution is subject to various constraints that differ according to each program (staffing, facilities, enrollment, student preparedness, etc.) all of which change over time. Given this landscape, it is not surprising that there are many different forms of first-year design courses, which periodically change in response to changing goals and constraints. One way in which these courses differ is the implementation of a learning activity whose purpose is to give the opportunity to students to follow the EDP (i.e. a design project). The literature describing design projects for introductory design courses is vast, so we limit our brief review to those programs, like ours, whose first-year design course is taken by all first-year students regardless of their eventual specialization and/or those programs which have a major in the same ABET Accreditation category as ours - "Engineering (Bachelor of Science)"

A review of the projects reported in the literature associated with first-year engineering design courses reveals fairly good consensus on several elements. Not surprisingly, most design projects provide a problem statement for the students to start with (i.e. they are not tasked with identifying a need) [2-16, 18-19, 21-26]. Providing a problem statement addresses student inexperience with the EDP. On the other hand, the few projects that require students to identify a need naturally focus on entrepreneurship [1-2, 5, 17, 20]. All projects reported in the literature require students to work in groups to complete the design process. Certainly, this provides a means for students to work on their communication skills, but it can also address logistical/budgetary challenges, most obviously not having to supply materials to *every* student. Most projects are either long-term (i.e. more than half of a semester) or short-term [1-5, 9-11, 14-16, 18, 20-22, 24-25] or long-term coupled with one or more short-term projects [6-8, 12-13, 17, 19, 23, 26, 27]. Most students who complete a first-year course like this one will likely specialize in a particular branch of engineering; thus, the project typically provides an introduction to various types of engineering [1-5, 7-9, 11-17, 19-23, 25-27]**.** There seems to be slightly less consensus on including instruction in project management [1-4, 8-10, 12, 14-15, 20-21, 23, 25-27] (often through the use of a Gantt chart), perhaps because on the spectrum of activities that excite and inspire students to continue in engineering, project management bends toward the mundane and boring. Finally, common to most projects is the fabrication of an artifact [1-10, 12-23, 26-27], certainly an exciting activity which can inspire students to continue in engineering.

Less common elements of a first-year design project (but nonetheless valuable) reported in literature include: the use of a "reverse engineering" activity [5, 12-14, 23] in which students disassemble a consumer product and then work to improve upon the design of the product; inclusion of computerized data acquisition or control [11, 16, 20, 26-27]; coordination and consultation with a client other than the instructor [15, 19, 23, 25-26]; and, in one case, working within the confines of a real budget using real money [12]. These less-common elements are likely driven by unique resources and circumstances at the various institutions.

One circumstance unique to our institution is our location near the first offshore wind farm in the United States [28-29], which provided much of the inspiration for our project. In December 2016 Rhode Island became the first state to generate energy from an *offshore* wind farm, when the five wind turbines off the coast of Block Island began operating. Our state has shown continued growth in wind energy, with seven onshore wind turbines installed in Johnston in 2018. Currently, the Revolution Wind Farm is being installed off our coast, which will send power from 88 turbines to both Rhode Island and Connecticut. Additional projects off the coast of Rhode Island, Massachusetts, Connecticut, and New York are in development as well, with the capacity to power 1.5 million homes [30, 31]. While the wind turbines off the east coast of the US will be built on towers attached to the sea floor, many of the wind farms on the west coast will be on floating structures because the Pacific Ocean is very deep close to shore. [32]

Project Overview

This first semester engineering course is a requirement for all undergraduate engineering students. The course roster includes mostly first year engineering students, although there are typically several sophomores enrolled (transfer students or students who have changed majors) as well as several non-engineering students who take the course either for a pre-requisite to another engineering course required for a minor or to fulfill a general education requirement. Students in the program at this point are typically undeclared engineering students and will choose a specialization of civil, computer, electrical, environmental, or mechanical in the spring of their sophomore year.

A semester-long design project is included in the course every year that requires the application of engineering graphics and the EDP. Students typically work in teams of 3-4 students to design wind turbine blades and a floating platform for an offshore wind turbine. The learning outcomes of the project include deepening students' understanding of the engineering design process, exploring various engineering disciplines, strengthening team-working skills, and growing their ability to document the engineering design process. Students are assigned the project in the first couple weeks of the semester and the project is due the final week of the semester. The project is organized into three major phases as described below.

Phase 1: Project Management

The goal of the first phase is to help students establish foundations of a strong team. During one class period, students learn how to create effective agendas and minutes for team meetings. Students also spend time in class learning how to read and create a Gantt chart. Teams then use part of the class time to create an agenda for their first meeting. The deliverable from this meeting is a Team Working Agreement (TWA) as well as the meeting minutes and a Gantt chart for their project. During the early phases of the project, students are provided with templates for meeting agendas. A template for a TWA is also provided, where students are required to respond to the questions listed in Table 1.

Table 1: Team Working Agreement Questions

Ground Rules	● What times in the week can you get together as a team? ● How much advance notice will you give before meetings? ● What behaviors are acceptable in team meetings?	● How will team members deal with disagreements? ● How will the team deal with absences? ● Under what conditions will your team choose to go to someone else for help?
Decision Making	● How will your group make decisions? Voting? Consensus? One member will dictate? Roll of dice?	
Communication	● How will you contact each other about meetings? (include the contact information)	
Roles	● Make a list of roles you expect you will need to complete the project and assign group members to each role. If you think of more roles than you have members, one or more members will have multiple roles.	
Outcomes	● Create a statement of your team's goals. Be specific about the goals of each team member. Probably, all team members want to "get a good grade," but does everyone agree what a good grade is? Do any or all team members want to create the best performing device, or is merely meeting a certain performance level sufficient?	

Phase 2: Mechanical & Electrical Engineering – Wind Turbine Blade Design

The goal of this project phase is for students to design and build wind turbine blades to extract the maximum energy from the wind (generated by a 3-speed fan). In this phase, students explore the roles of mechanical and electrical engineers. Students measure the energy and power produced by the generator when the turbine spins using a Labquest 2 data acquisition unit with an Energy Direct sensor. Students are given components from KidWind turbine kits [33] and design blades to fit the existing base, tower, and nacelle, attaching the blades to the holes in the hub which fits up to 12 blades. For prototyping, each team is provided one roll of duct tape, access to unlimited standard printer paper, and 10 sheets of cardstock. Students can also use the miscellaneous consumables found in the course supply closet (e.g., paper plates, straws) and have access to basic tools like scissors and small handsaws.

This second phase is broken up into smaller milestone deliverables with deadlines to help students stay on track as they develop their project management skills. The milestone topics reinforce the steps of the EDP discussed during the class lessons. First, students develop a problem statement with design criteria and constraints. Then they generate design concepts and evaluate the different design ideas against the criteria they established. They also create hand drawings and prototypes of some of these initial designs and test them to provide quantitative evidence for choosing the best design. LabQuest [34] units are used to measure the energy and power performance of the prototypes, which help students select the optimal blade parameters. Finally, the teams design their final prototype and present their solution during class time during final energy and power tests. Further details about the milestones are provided in Table 2.

Table 2: Phase 2 milestone schedule

Milestone	Description of the Deliverable
1: Problem Statement	A typed mini-report that describes the problem statement in paragraph form. The first few sentences should describe why the work is being done. The final sentence should begin with "Design a…" and include discussion of constraints and criteria necessary for achieving success. Be very mindful about writing this statement in your own words. Additionally, include lists of the "should criteria" and "must criteria". Also include a list of constraints.
2: Generate Concepts	A typed mini-report with hand sketches describing multiple solutions, including the materials for fabrication. Each sketch should be accompanied by a brief written description and credit to the artist/creator. Your report should demonstrate contributions from all group members.
3: Compare Designs and Make Decisions	A typed mini-report with a description of the process used to select the best possible solutions among the multiple presented. Your selected designs will be used during milestone 5, so the report should also include detailed documentation of your plan for parameter testing. You must also describe the planned construction process in words.
4: Hand Drawings	Deliver hand drawn dimensioned sketches of your team's alpha designs that will be used in parameter testing. The hand drawings should be scanned and inserted into a digital document. Use captions to label all drawings.
5: Prototyping	Perform thorough parameter testing. That is, measure the energy and/or power performance of the various alpha prototypes using the LabQuest equipment. The goal is to identify the optimal blade parameters for building an eventual beta prototype. (Blade parameters include blade size, shape, pitch angle, and number of blades.) Your report should include completed tables of data and a description of your testing process.
6. Present Solution	Work together to create a beta prototype: a complete set of turbine blades manufactured with paper, cardboard, tape, or other materials found in the course supply closet (these blades will be used for your final power and energy production tests). Your test results include: ● Electrical energy measurements from your final blade design across range of fan settings ● Power curve for your turbine (a plot of power vs air velocity)

Phase 3: Civil & Environmental Engineering – Tower and Platform Assembly Design

The goal of this phase is for students to design, build, and test a support structure (tower) and platform for a floating offshore wind turbine (FOWT). In this phase, students explore the roles of civil and environmental engineers since their design is assessed based on both its stability and its environmental impact.

$$Score = \frac{Moment}{Environmental\ Impact}$$

Each team is given 100 bamboo skewers, a roll of string, a roll of duct tape, and access to hot glue guns. Teams can also use an unlimited amount of recycled paper products (e.g., cardboard), recycled plastic products (e.g., water bottles), recycled aluminum products (e.g., soda cans), and rocks/sand. Students cannot purchase any new materials. The floating platform assembly needs to fit within a tank of water (H 18 in., W 36 in., D 20 in.) with a water depth of 14 inches. Platforms must attach to the tank using mooring lines (chain) from the bottom corners of the tank. When installed on the moorings, the tower-platform cannot touch the walls of the tank. The tower also needs to support a stability testing device with an outer diameter of 1.375 inches, an inner diameter of 1 inch, and a length of 2 inches. The water basin and testing apparatus are shown in Figure 1, attached to a student team's designed floating platform and tower assembly.

Figure 1. The test tank including a student-designed platform. Note the reinforcing collar that attaches to the mooring chains and supports ~400 lbs of water. A weight is put into the cup some distance from the top of the tower to apply a moment.

Towers and floating platforms are evaluated based on a combination of a moment score and an environmental impact score, as shown in the equation for "score" above. The moment is determined by hanging a mass a certain distance along the meter stick in the stability testing device. Students can choose the amount of mass and the distance to use during their test. The test is deemed complete when any of the following occurred:

1) the protractor showed a pitch angle of 20 degrees of more,
2) the platform touched the sides or bottom of the container,
3) the tower no longer supported the test device at least 18 inches above the water level in the tank.

The environmental impact score is calculated by each team based on the types and amounts of materials they use in their designs. Teams estimate a CO_2 emission equivalent to simulate the emissions generated during the processes within the lifecycle of the wind turbine, including materials production, transportation, construction, maintenance, decommissioning and dismantlement. The instructors developed a lb. CO_2 equivalent "cost" for each material used in the tower-platform design, and in order to incentivize the use of recycled materials, the CO_2 equivalents for recycled materials were lower than other materials supplied. The lb CO_2 equivalent "costs" are listed in Table 3. Students are required to keep track of the materials they used in order to calculate a final score.

Table 3: CO_2 equivalents for each material used in design of the floating tower/platform

Materials (each team will receive the following):	Environmental Impact
100 bamboo skewers	1.5 lb CO_2 equivalents per lb 1 skewer is 0.002 lbs
Roll of String	0.01 lb CO_2 equivalents per foot
Recycled paper products (e.g. cardboard)	0.25 lb CO_2 equivalents per lb
Recycled plastic products (e.g. water bottles)	2 lb CO_2 equivalents per lb
Recycled aluminum products (e.g. soda cans)	2 lb CO_2 equivalents per lb
A roll of duct tape	10 lb CO_2 equivalents per lb
Hot glue	15 lb CO_2 equivalents per lb; 0.0084 lbs per glue stick
Rocks, sand, or water may be used for ballast	Zero lb CO2 equivalents per lb

Phase 3 is similarly broken down into several milestones with deadlines for the students to complete. The milestones follow a similar format to the ones for Phase 2, reinforcing the engineering design process steps. The final testing of the designs is completed during class. The milestones of Phase 3 are further detailed in Table 4.

Table 4: Phase 3 milestone schedule

Milestone	Description of the Deliverable
1. Problem Definition and Initial Designs	Write a typed mini report that contains a problem statement for phase 3 including a list of must and should criteria. Include any/all research on the types of floating platforms that you conduct. You must cite your work in the text and include a bibliography. In addition, the mini report should document your initial designs.
2. Compare Designs and select, build, and test final design	Using a design selection matrix, select your final design. Work together to create a prototype of the tower-platform assembly. This will be the design you test in class. Conduct testing of your prototype and iterate to earlier design steps as necessary to try to optimize your design. Write a typed mini-report that documents your design selection process, explains your manufacturing process, and describes the testing and iteration steps you took.
3. Final Design and Report	See Appendix

A template is provided to the students for the final report, which requires students to document the different steps of the EDP. Students use the previous milestones and comments from the instructors to complete their final document. Additionally, students are required to include all their team meeting minutes as well as personal reflections about the project and their contributions. Bonus points are awarded for the top three performing teams during the tower-platform stability testing. The requirements of the final report can be found in the Appendix.

Methods

This paper assesses the effectiveness of a semester-long course project from an introductory engineering course that aims to fulfill various course learning outcomes. These outcomes include fluency with the EDP, development of professional skills, strengthening teamwork, growth in project documentation, and exposure to different subfields of engineering. Two methodologies are used in this work, direct and indirect assessment, further outlined below.

First, the efficacy of the course project in meeting the above outcomes is conducted via direct assessment of student work, in the form of reflections in their final reports. That is, "teacher research" [35-37] is conducted to explore student created artifacts for evidence of achieved learning outcomes. The institution's Human Subject Review Board (HSRB) approved the use and analysis of student artifacts for individuals who provided consent. Of the 89 students enrolled in the course in the fall of 2023, 41 students consented to the use of their work, with names and other identifiers removed. Reflections written by students in their final reports were explored thematically, where each individual's written response could be counted for multiple theme areas. One drawback of this approach is that students included their reflections in a shared group report, such that some responses may not have been completely honest about division of labor, as all group members could read each other's comments. The results of exploring students' reflections are presented in the following section.

Next an indirect assessment is performed through analyzing the results of the end-of-semester course survey. Of the 89 students enrolled in the course, 67 completed the survey following their final submission of the course project. Participation in the survey was not incentivized. Students responded to a series of questions, including eight Likert-type questions, a select all that apply (SATA) question, and two open-ended questions. Means and standard deviations are calculated for the Likert-type questions, where strongly disagree and strongly agree are assigned values of 1 and 5, respectively, such that larger means indicated greater levels of agreement by the students. The SATA question is analyzed by the percentage of students who selected each item. Finally, the open-ended questions are coded thematically and the frequencies are counted, where each response could only fall into one theme area. Numerical and thematic responses are used to assess the efficacy of the course project in meeting student learning outcomes described above.

Results and Discussion

Direct Outcomes Assessment from Student Reflections

Each student contributed a personal reflection in Appendix B of their team's Phase 3 final report. Their reflections included responses to four questions, listed in Table 5, above. This work explores responses to Question 2: "What did you learn from completing the project?" Most students wrote full paragraph responses to the prompt, with a few providing only a brief sentence.

Student responses were coded into four theme areas, including the engineering design process (EDP), soft skills, tools, and applications. Within these theme areas, more specific topics were identified. The EDP theme includes general mention of the EDP, as well as more specific components such as iteration, prototyping and testing, and gathering information. Under the umbrella of soft skills, topics include teamwork, communication, and time management. Student responses also contained mentions of specific tools that were taught over the course of the semester, and these fell into the categories of organizational tools and CAD modeling. Finally, the theme area of applications was broken into the two areas of specific mention of wind turbines or floating platforms, and sustainability.

Table 6: Thematic responses to student reflections in their Phase 3 final reports to the question "What did you learn from completing the project?"

Theme Area	Topic	Count (n = 41)
Engineering Design Process	Engineering Design Process (general)	17
	Iteration	5
	Prototyping and Testing	3
	Reporting/Documentation	3
	Gathering Information/Research	2
Soft Skills	Teamwork/Collaboration	23
	Communication	10
	Time Management	10
Tools	Organizational tools	11
	CAD Modeling	4
Applications	Wind turbines, floating platforms	8
	Environment/Sustainability	3

Each student's written response was examined for mentions of any of the topic areas listed in Table 6. Each response could be counted in multiple topic areas. The frequency of topics mentioned in student reflections are shown in the right-hand column of Table 6. The theme areas are discussed further below, including example pull quotes as evidence.

There are of course many versions of the EDP, but in this course the instructors selected a six-step process, matching the milestones outlined in Table 2. Students shared that the project was helpful in cementing the steps of the process and deepened their appreciation in a way that could not be accomplished by sitting in a classroom.

> I learned so much about the engineering design process. We had to memorize the steps for class but conducting them is another story.

> I was able to truly comprehend the steps of the engineering design process. It is straightforward [sic] to memorize the 6 steps, but engaging in each step permitted me to receive a different lens on the whole process, truly improving my understanding.

Some responses went deeper, to specifically name steps or components of the EDP. For example, five students mentioned the iterative and cyclical nature of the EDP.

> By following the steps, and demonstrating iteration, we were able to have an incredible final product.

> I learned how the steps of the engineering design process are used throughout a course of a project. This project also supported the idea that the design process continues to go in a circle.

Related to the need for iteration in achieving a successful design, three students discussed their growth in knowledge and appreciation of the prototyping and testing step of the EDP.

> I also learned how difficult it is to make prototypes, especially effective ones.

> Something that I learned from this project was the importance of having and testing multiple designs. Having and testing multiple designs allows for the tester to compare and contrast the designs. This allows for the best parts of each design to be combined for the best possible outcome

The six-step EDP that was adopted in this course did not include steps such as “gathering information” or “documentation.” Instead, these components were discussed as steps that may happen at any time, or even multiple times, throughout the EDP. Students pointed to these two components, demonstrating their broad understanding that the EDP can encompass more than just six cyclical steps.

> Our design for the turbine blades included less research and more speculation, which did not benefit us when testing.
>
> I learned how to adequately follow the engineering design process, format design documents and reports.

Another common theme encountered in students’ reflections was their gains in softer skills, such as teamwork, communication, and time management. The most frequent topic mentioned in student responses was teamwork, with 23 of 41 students including it in their reflection. Students reflected on the uniqueness of working with the same team throughout the entire semester.

> I have rarely worked with a single group for so long in the past and I see the benefits from forming friendships. We trusted each other to complete assigned responsibilities and were understanding about struggles or difficulties that came up.
>
> I would say I learned the most about working in a team for a longer form project. In the past, projects done in groups would be a few weeks long at most, but I am happy to have had the opportunity to work with this group over this semester!

Students shared a sense of pride at what they could accomplish with their peers, while others took a more reflective stance on how things might have gone better with strengthened communication and time management.

> It was amazing how much 4 people were able to achieve with strong minds and strong communication.
>
> The biggest thing I gained from this project was an understanding of the importance of communication and time management. After the first part of the project I stepped back from organization which resulted in the communication amongst us falling apart.
>
> Going forward I know that I need to be in constant communication with my teammates, even if nothing is getting done over a certain period of time we still need to be talking about either the best way for us to catch back up to schedule or adjusting the schedule itself.

Time management was another common theme under the umbrella of soft skills, where students discussed needing to meet the challenges of coordinating multiple team members’ schedules and meeting deadlines.

> Throughout the course of the project, I learned how to manage time not only around my schedule but the schedule of others as well as helped to better my team work skills.
>
> This also ties in with time and project management, which would not have been achieved if it wasn’t for our Gantt chart. Each week [a team member] would update the Gantt chart. This was the basis that we all worked off for this whole project and really helped us with our deadlines.

To support the development of these soft skills, various tools were introduced throughout the course of the semester, including Team Working Agreements, Gantt charts, concept selection matrices, as well as meeting agendas and minutes. Many students pointed directly to one or more of these tools.

> I have learned the importance of things like agendas and working agreements and how they are used in a professional setting.

> The Gantt Chart ensured that we stayed on task and head [sic] of schedule.

> I learned how to write meeting minutes and type mini reports for team meetings.

The introductory course also included lessons on computer-aided design (CAD) software, including AutoCAD and SolidWorks. Students were required to create 3D models in SolidWorks as part of their Phase 3 deliverables. Some students reflected on their growth in use of CAD software thanks to the project.

> I gained a much better understanding of SolidWorks while I was working to complete the models.

Finally, mention of a specific application was identified as fourth theme area. Eight students cited an enhanced understanding of wind turbines and/or their floating platforms.

> I learned more about wind turbines, which is a topic that I am interested in pursuing in the future, and how they can be implemented to create clean energy.

> I also learned a lot about buoyancy when it comes to the science of the floating platform and air flow when it came to the wind turbine which was fun to learn about.

Students also commented on their growth in appreciation for environmental impacts and/or sustainability.

> I also learned the importance of sustainability in the construction of these platforms.

> I learned a lot from this project such as how much environmental impact a build has on the world.

Anecdotally, teams with poorer performance on the final testing day were able to reflect verbally with faculty that they wished they had done more testing and reiterating on their designs throughout the project. Meanwhile, a student from the top performing team across all four sections of the course, shared a particularly rich reflection about the EDP and soft-skills, shown below.

> Upon completion of the project, I learned a lot. To start, I learned about how effective the engineering design process is. […] I was also able to learn how to effectively communicate and collaborate with a team to reach a common goal. Mainly, however, I was able to learn about time management and how to make the most of the time I had during the day, whether that be through construction, or with writing/analysis.

Future work could include a deeper and more thorough analysis to corroborate student performance with their discussions of the EDP in their reflections.

Indirect Outcomes Assessment from Student Responses to End-of-Course Survey

The results of an end-of-course survey containing questions related specifically to the semester-long course project are presented here.

First, students were asked to respond to the prompt "The semester-long design project strengthened my understanding of the following steps of the engineering design process:"

- Define the Problem
- Define Criteria
- Generate Ideas
- Compare Designs & Make Decisions
- Prototype and Test
- Present Solution
- Iteration
- Gather Information

Responses were gathered using a Likert-type scale from strongly agree to strongly disagree. Strongly agree and strongly disagree were assigned numerical scores of 5 and 1, respectively, such that means and standard deviations could be calculated. The results are presented in Figure 2. The first six items, which correspond to the steps of the EDP adopted for use in this course, all scored a mean value above 4, indicating that most students felt that the semester-long project strengthened their understanding of those components. These six steps also match the milestone framework used in Phase 2 of the design project.

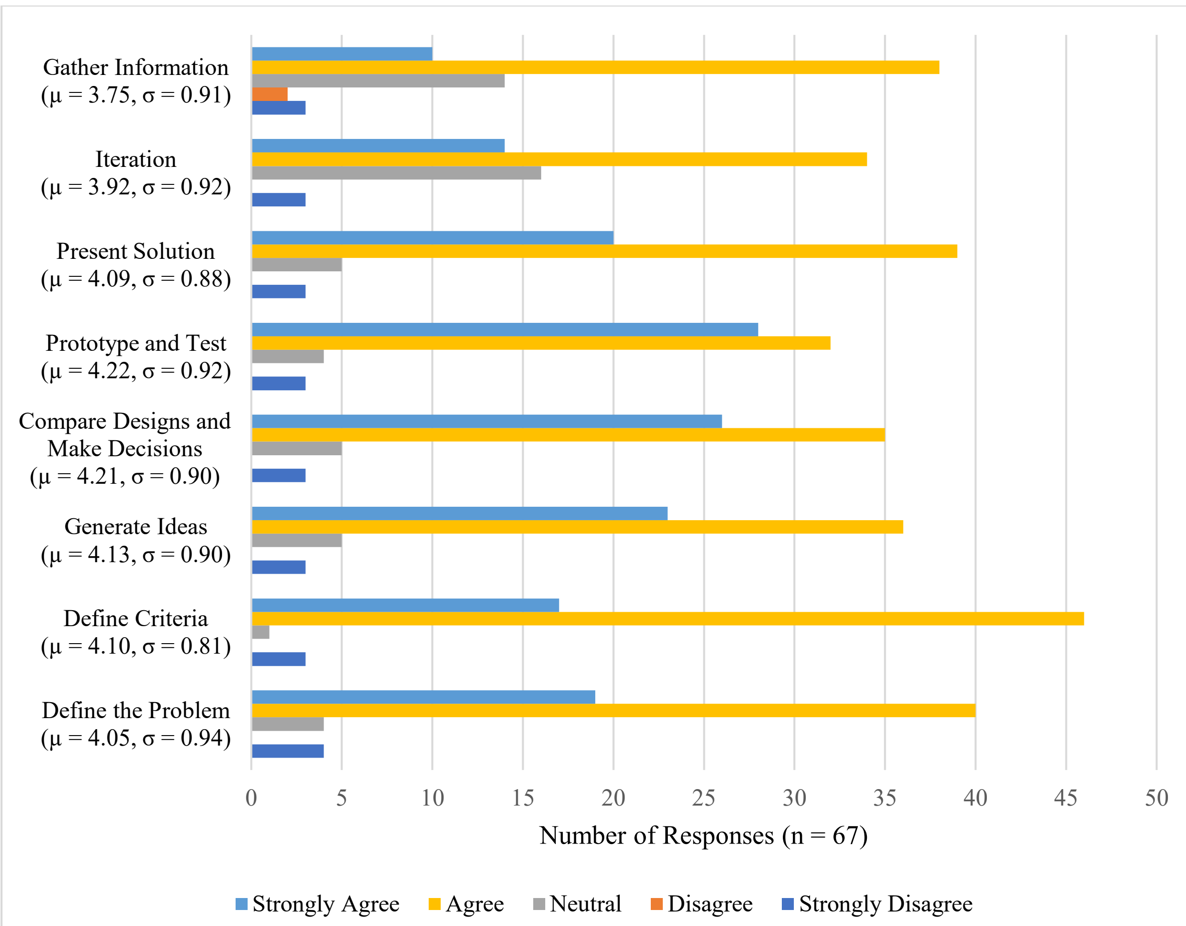

Figure 2. Responses to the survey question: "The semester-long design project strengthened my understanding of the following steps of the engineering design process."

The iteration and gather information steps, neither of which were included as official steps in the course's adopted EDP, score means values just below 4. While many students agreed that they grew in their understanding of those components, the agreement was not as strong as the other six steps.

Next, students were asked “Which of the following skills were strengthened by your participation in the semester-long wind energy design project (select all that apply):”

- Time management
- Project planning
- Teamwork
- Written communication
- Visual communication

Results are shown in Figure 3, where 66 students responded to this question. The percentage of students who selected each item was calculated and is displayed in Figure 2 from most frequently selected (95%) on the left to least (45%) on the right. The vast majority of respondents felt that their project planning skills were enhanced, followed by teamwork (83%), written communication (70%), time management (68%), and lastly visual communication.

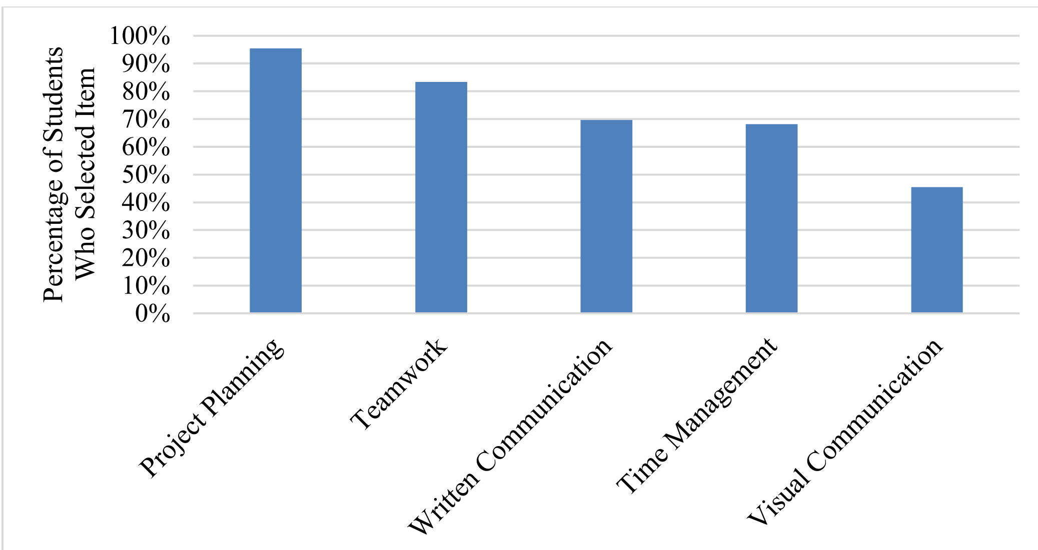

Figure 3. Responses to the survey question: “Which of the following skills were strengthened by your participation in the semester-long wind energy design project (select all that apply).”

Finally, the survey ended with two open-ended questions. The first asked students “What advice would you give to next year's ENGR110 students to be most successful in the semester-long design project?” Responses were provided by 67 students and coded by theme, where each student’s answer could fall in only one thematic category. The results are presented in Table 7, including the frequency (n) of the theme and an example pull quote from the survey. The results show time management as the most common response, with 18 of 67 students. Advice around team communication and the suggestion to meet regularly were next, followed by technical guidance. Other students recommended paying strong attention to instructions, remaining very organized, keeping a positive attitude, and performing detailed background research. Seven of the 67 responses pertained to the course in general, as opposed to the semester-long project. Finally, one student did not have constructive advice as they felt that “everything went well.”

Table 7: Responses to the survey question "What advice would you give to next year's ENGR110 students to be most successful in the semester-long design project?"

Theme	n	Example Student Quote
Time Management	18	"Make sure that you give yourself enough time and don't wait until last second because if the project doesn't work on the first go you want enough time to come up with another solution."
Communication	9	"Make sure you have good communication with your group about the expectations of each group member and try to split the work as evenly as possible."
Meet Regularly	9	"Be prepared to work outside of class with others in your group regularly. The more time and effort you put into your project, the better it's gonna be."
Technical/EDP Advice	6	"Make sure to test your designs as soon as you can to give yourself time for iteration."
Read Instructions	5	"Always look at all the rubrics and cross reference with the design document to make sure that you have all of the proper information in your report."
Organization	5	"Stay super organized, the Gantt chart is great but you need to also keep in contact with your group on what's due when."
Attitude	4	"Just keep an open mind and positive attitude"
Research	3	"I would try to do outside research before creating concepts as real life examples are helpful and effective. Also, going simple can be better than an extravagant idea."
General Course Advice	7	"Dont [sic] miss any homework. Be on time to class. If not you will lose a lot of information. Do all ypur [sic] homeworks on time. Don't [sic] leave it to the night before submission."
No Advice Provided	1	"I think everything went well"
Total Responses	**67**	

The second open-ended question asked students "What suggestions do you have for the instructors to improve the project for next year?" Again, responses were sorted thematically. The results are shown in Table 8. Of the 50 students who responded to this prompt, 15 of them either did not have a suggestion or had only positive things to say about the project. On a more constructive note, twelve students encouraged the instructors to improve their communication and/or instructions about the project, especially in relation to the design testing days. Other students suggested using more class time to work on the project, as it was challenging for students to find times when all team members were available outside of class. As with the previous prompt, some responses were about the course in general, rather than project specific. Lastly, four students suggested switching the team assignments between Phases 2 and 3. The frequency of the responses by theme, as well as example quotes, are provided in Table 8.

Table 8: Responses to the survey question "What suggestions do you have for the instructors to improve the project for next year?"

Theme	n	Example Student Quote
N/A or Positive Response	15	"None, I loved this project and I learned a lot."
Better Communication from Instructor	12	"More clarity on what is going to happen on testing day specifically like what it's being tested on and the different changes your design will see."
Miscellaneous	8	"I would have the feedback at the end be anonymous so that we could write how the others contributed without making enemies."
More Time to Work on Project During Class	6	"More time to work on designing in class"

General Feedback About Course	5	"Have a slower pace when giving instructions for AutoCAD and SolidWorks. Please continue having a tutor in class, it really helps."
Groups/Team Assignments	4	"One suggestion would be switching up the groups after the two phases. For one it will allow the students to communicate with more people. On top of that it will allow them to get a better sense of teamwork."
Total Responses	**50**	

Conclusions and Suggestions for the Future

There are many competing criteria that a first-year engineering design project aims to fulfill, e.g. introducing various engineering disciplines, reinforcing learning about the EDP, being fun and challenging enough to engage students while not becoming discouraging. While no project can balance all criteria perfectly, the project presented here was largely successful the in achieving listed aims.

In a general engineering program, it is important to introduce first-year students to all of the subdisciplines offered so that they can make an informed choice when they choose their specialization. While the floating wind energy project presented here was chosen by faculty for its aspects of mechanical, electrical, civil, and environmental engineering, this fact was not discussed in either direct or indirect outcomes by our students. One future improvement to this project could be to make the interdisciplinary nature of the project more explicit for the students, perhaps through an assignment.

From the analysis of student reflections, 17 of 41 students mentioned the EDP, usually discussing how the project strengthened their understanding of one or more of the design process steps. While this shows that at least some students were thinking about the EDP when preparing their reflections, notably, 24 of the students in the study did not mention the design process, which could be an area for improvement for future iterations of the project. The area that most students talked about in their reflections was soft skills, with 23 of the students mentioning an improvement in their teamwork skills. Multiple students mentioned that the semester-long nature of the project allowed them to get to know their teammates, which inspired better teamwork.

The success of the project in reinforcing student learning about the EDP is apparent from the survey results, consistent with the general findings from analysis of student reflections. As discussed in the Results section, students particularly identified that their knowledge of the "prototype and test," "compare designs and make decisions," and "generate ideas" steps were strengthened by their work on the design project. In addition, students felt that soft skills like teamwork and project management were greatly strengthened by this project. Again, a finding that was consistent with the themes identified in student reflections.

While the majority of responses to the question of "What suggestions do you have for the instructors to improve the project for next year?" in the end-of course surveys were "N/A" or some sort of positive response, 25 of 50 responses did contain constructive feedback from the students. Their ideas about how the project could be strengthened included better communication from instructions, most specifically about clarity on what to expect on design testing days. This suggestion is noted and will be addressed both through strengthening the description in the assignment document as well as improving the explanation in classes leading up to the testing days. Six students suggested dedicating more class time for students to work on designing, five responses were in respect to the overall course and not the project specifically, and four students recommended changing the team assignments after the second phase. In addition, based on student feedback, instructors will consider different ways to get more accurate feedback and reflections on the teamwork aspects of the project at the end of the semester.

From the course instructors' perspective, there are opportunities for further improvements to the project, most notably in the actual mechanical design of the project and testing apparatus. One suggestion is to have two testing setups for the floating platform phase in order to both streamline the testing day and allow more groups to prototype at the same time. Additionally, the application of the moment on the top of the floating platforms had some issues with the mass sliding and twisting; some simple changes to the testing device could remedy these issues.

The last important criterion for a first-year engineering design project is to have an appropriate level of difficulty. The instructors noticed a difference between this year's project and previous offerings, which did not feature the floating platform in Phase 3, but rather just a tower. The addition of the floating platform to this phase of the project helped to bring the level of difficulty to the point where students felt they needed to rise to the challenge and instructors noticed that there was much more student involvement in prototyping and testing outside of classroom hours. This led to the students having fun and taking ownership and pride in their designs.

This success of this project is in many ways due to revisions faculty have made since its introduction in the fall of 2019. Over the years, we have found a few factors in our syllabus design and project organization that have been particularly helpful with supporting students. The scaffolding of the assignment with phases and milestones demonstrates project management to students, while also keeping them on-track. It has been effective to repeat the design process twice (in Phases 2 &3), with the first time including more guidance. Also, it was a good investment to dedicate class time early in the semester in order to successfully launch team dynamics and understanding of the project steps. Additionally, requiring students to schedule time to use the test-rigs and measurement devices encouraged teams to coordinate schedules and take responsibility in showing up.

Team-building is an important component of this project, not only for developing a sense of community among first-year engineering students, but also because it presents an opportunity to engage in discussions around DEI and social justice. While faculty have implemented some practices aimed towards equity – each team receives the same materials, students are required to complete a Team Working Agreement (TWA), and considerations of gender-diversity across and within assigned teams – there remain further opportunities for improvement. Future implementations will aim to deepen discussions of DEI, for example by creating lessons to explore the varying impacts of wind energy development across diverse communities.

This first-year engineering design project, with a focus on wind-energy, was successful in inspiring students to learn both about the EDP and soft skills like teamwork, largely due to it being a challenging and fun project that students enjoyed spending time on. Future implementations will heed suggestions from the students and instructors, with an aim of deepening students' understanding of the differences between the engineering subdisciplines.

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Appendix

Table A: Final report requirements

Digital Binder Sections	Description of the Section
1: Introduction	● Problem statement ● List of important criteria, distinguishing between “should” and “must” criteria ● Description of existing wind turbine tower-platform assemblies for floating wind turbines. Images are encouraged. Cite your sources.
2: Concept Generation	● Hand sketches describing multiple solutions including suggestions for fabrication materials and fabrication method.
3: Compare Designs and Make Decisions	● Description of the process used for selecting the best solution among the initial concepts. Numerical justification is highly encouraged here as well. ● Detailed explanation of your chosen design
4: Prototyping and Testing	● Description of your prototyping and testing process ● A 3D model of your design made in SolidWorks ● Dimensioned 2D drawings made from 3D models
5. Present Solution	● Description of the manufacturing process, including images documenting the building process and a photo of the final assembly. ● A description of the performance of your final design. What was the failure mode during testing? ● What was your calculated environmental impact? ● What was your final score (moment supported/CO_2 equivalents)?
Appendix A	Meeting minutes in chronological order
Appendix B	Personal reflections from each team member answering the following questions: 1. What did each person contribute to the project? 2. What did you learn from completing the project? 3. Imagine that sometime in the future (either as a student or practicing engineer), you are part of a group of people working to solve a problem for a client. The members form a diverse group (different academic disciplines, different ethnic and racial backgrounds, socio-economic classes, etc.) including some for which your primary language is not the same as theirs. Please respond the following questions about the group a. List specific steps (5 or so) will you take to foster a collaborative and inclusive environment in this group b. List ways that you would establish goals, plan tasks and meet objectives
Demonstration of effective use of MS Word for creating a high quality report	● Cover sheet ● Table of Contents ● Headings and subheadings ● Table of Figures ● Lists/Bullets ● Figure and table captions ● Equations and captions ● Works cited and cross references
Bonus Points	5 points for most energy converted, 4 points for second place, and 3 points for third place.