(GIFTS) Designing for Daily Life: Open-Ended 3D Modeling in First Year Engineering

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Dr. Barillas's focus is on first-year engineering education, student engagement, interdisciplinary learning, and inclusive pedagogy. As Program Director for ID3EA, she has led curriculum development initiatives that integrate hands-on design, teamwork, and real-world problem-solving into the foundational course sequence. Her teaching emphasizes active learning, student-centered instruction, and the development of professional skills such as technical communication, collaboration, and ethical decision-making.

Her research interests include interdisciplinary education, curriculum innovation, and the retention and success of underrepresented students in engineering.

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Introduction

First-year engineering students often expect structured, well-defined problems. To challenge this mindset and develop creative problem-solving skills, we implemented an open-ended, individual 3D design project in the first part of Rutgers University's new first year engineering two course sequence (ID3EA). This project was assigned after students learned the engineering design process and 3D modeling using Onshape®. They were tasked with creating a functional 3D-modeled item to improve their daily life while meeting criteria and constraints that they defined. This project not only promoted active learning and creative thinking, but also intentionally introduced some ambiguity, challenging students to operate without step-by-step guidance, a key aspect of real-world engineering practice [1, 2].

Curricular Activity

Students were tasked with applying the engineering design process to create an original 3D model in Onshape®. Prior to the assignment, students were introduced to Onshape® through in-class tutorials on sketching, extruding and dimensioning. Our first tutorial was adapted from materials provided by the Mechanical and Aerospace Engineering Department at Rutgers University and it included designing an engineering dog bone which is typically used in tensile testing [3]. Students followed along with the instructor to complete the design. The next modeling assignment was completed during our co-taught lesson with the Chemical and Biochemical Engineering Department. This lesson was a hands-on activity where the goal was for students to design a mixer that can effectively make protein shakes. Students were asked to go through the following design process: empathize, define, ideate, prototype, and test. During class the students identified design constraints to make an optimal protein shake for their team [4]. To test their design the students determined which parameters to keep constant, how they will measure results, and how they can ensure the results are reproducible. Then they took the ingredients (protein powder, milk, water) and mixing tools to investigate the best mixing tool to effectively mix the protein shake. After completing this experiment, students were asked to individually design a mixing tool in Onshape® that would fit inside the container's geometry. This allowed students to start working with given constraints on size.

Students were asked to 3D model an object they would use in daily life and write a memo describing their work. The grading rubric shown in Table 1, was adapted from the PA Media and Design Competition [5]. As part of the assignment, they defined three design constraints, such as measurements, cost, aesthetics, manufacturing, or sustainability, that their item needed to meet. The design had to be entirely their own work and address a real need or challenge they encountered in their day-to-day experience. Students were given one class period to work on this, but in the future, they will be given more class time to do this as many of them worked on it outside of class. In addition to the 3D model, students submitted a memo describing: how they completed each step of the engineering design process, a description of the item, how they determined their constraints, an explanation of how it met their specified constraints, and a discussion of how their design met their design goals. As a scaffold students were provided with an exemplar of this memo. Students were assessed on the functionality of the design, adherence to constraints, quality of technical writing, and visualization. For students seeking an additional challenge, the option was provided to learn how to 3D print their design.

Table 1. Individual Project Rubric

Criteria	Ratings
Functional Model (40 points)	**40 pts:** The object meets the criteria and constraints and is functional. **30 pts:** The object mostly meets the criteria and constraints and is mostly functional. **20 pts:** The object somewhat meets the criteria and constraints but is not functional. **10 pts:** The final object neither meets the criteria and constraints and is not functional.
Content (40 points)	**40 pts:** Fully connected the item produced to the problem using the engineering design process. Explains thoroughly how the object meets all criteria and constraints. **30 pts:** Mostly connected the item produced to the problem. Explains how object meets most criteria and constraints. **20 pts:** Somewhat connected the item produced to the problem. Somewhat connects how the object meets most criteria and constraints. **10 pts:** Does not connect the item produced to the problem or describe the connections to the criteria and constraints.
Conventions (10 points)	**10 pts:** Concise and well-written with no spelling or grammatical errors in the project or narrative. **7.5 pts:** A few spelling or grammatical errors occur in either the project or narrative, but it does not detract from the overall project. **5 pts:** Some spelling or grammatical errors occur and detract from the overall project. **2.5 pts:** Numerous spelling and grammatical errors.
Visuals (10 points)	**10 pts:** effective visuals **7.5 pts:** Used visuals **5 pts:** No visuals beyond the 3D modeled object **0 pts:** No visuals

Results and Discussion

Assigned in Week 3 of the first semester and due in Week 8 of the semester, this project provided an active learning experience that reinforced students' understanding of the engineering design process in a hands-on, personally meaningful way. By applying the process to a self-identified problem, students moved beyond theory to practice, gaining experience in problem definition, constraint management, and iterative design. Despite initial discomfort with the open-ended nature of the task, students successfully navigated the challenge, demonstrating creativity and critical thinking. Their projects addressed a wide range of practical needs, including a cellphone holder designed to fit dorm room bed frames, a frame to organize and store eyeglasses, and a hook multiplier to increase the number of usable hooks built into dorm room walls. These solutions not only showcased their design skills but also reflected thoughtful consideration of user needs, constraints, and manufacturability. One measure of the student's engagement in the individual project is the completion rate of this assignment. 1,032 out of the 1,050 (98.3%) students in the course completed the individual project with varying levels of success (average grade was an 88.5%).

Several students commented that they enjoyed the freedom to solve a real problem in their lives and appreciated the opportunity to personalize their designs. Approximately 6% of the students accepted the additional challenge of learning to 3D print their items, gaining hands-on experience with fabrication. The skills developed during this project, particularly in 3D modeling and design iteration, contributed to students' success in the final group design project later in the semester, ensuring all students had the technical foundation to contribute effectively.

Ensuring that students' submissions were original designs posed a known challenge given the ease of access to publicly available models. Students were encouraged to share their inspirations in their written memo. If they were adapting an existing design or using a video for assistance, they were expected to provide the reference and modify the design to address their specific, self-identified needs or constraints. Full time faculty, part time faculty, and teaching assistants were asked to review the version history in Onshape® to confirm that the models were developed over time. While not every model was individually verified due to course's scale and distributed instructional staffing, students were reminded that submission of unmodified public models would be considered a violation of academic integrity.

Acknowledgment
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References

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