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Work in Progress: Increasing motivation in large design courses through a scalable and unique project structure using collaborative competitions

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Abstract

Facilitating learning in introductory engineering design is easier and more effective when students are intrinsically motivated to strive for the best outcomes, have a low-stakes, but compelling, design challenge from an authentic client, and supportive teams and peers. Implementing these aspects at scale in large departments presents logistical difficulties.

Two years ago, in our large engineering "Introduction to Capstone Design" course (approximately 200 students), we restructured our design challenge to better balance these motivation and implementation challenges using a common design prompt paired with several real-world "clients", each with distinct needs. This structure enabled meaningful peer design reviews within studio sections, a friendly competition between teams working with the same client, and a manageable way of supporting the design projects with infrastructure and mentorship.

To strengthen students' engagement and user-centered design skills, each team identified additional requirements through recorded client interviews and progressed through a sequence of milestone design reviews. We report on early outcomes from two consecutive course offerings, drawing on course evaluations, mid-quarter feedback, and post-capstone surveys. Preliminary results suggest improvements in student motivation, perceived preparedness for capstone, and overall course satisfaction. We discuss implementation details, the generalizability of the approach, and opportunities for additional systematic evaluation.

Introduction

Introductory engineering design courses are critical in the undergraduate engineering education curriculum. They equip future engineers with the fundamental design thinking, technical, and professional skills required in real world applications [1]. These courses typically expose students to the full design process from defining the user needs, to generating ideas, evaluating concepts, analysis, and prototyping while building strong communication skills and decision making. Teaching introductory engineering design is not only foundational for future engineers' training, but also directly aligned with ABET criteria 3.2 and 5.d [2]. Programs often integrate introductory design early in the curriculum to equip students with the competencies, behaviors, and mindsets needed for success in the subsequent capstone design experience. At our institution, the Department of Mechanical Engineering at the University of Washington (Seattle), our introductory engineering design course is placed later in the curriculum, just before their senior design projects and has historically received poor evaluations from students.

Based on student feedback and challenges noted by instructors, we restructured the design project for autumn 2024 to address three primary goals: (1) enhance student motivation, (2) strengthen customer-focused design skills and (3) make facilitation feasible at large scale. This paper describes the resulting structure and examines its early implementations (autumns 2024 and 2025) and the preliminary results toward achieving these goals. We propose broad areas for future work but focus this initial assessment on the following research questions:

- RQ1. Does the new structure improve students' perception of the course as valuable and their intrinsic motivation to engage with design work and peer design reviews?
- RQ2. Does the new structure increase perceived preparedness for capstone relative to the prior structure?
- RQ3. Does the new structure allow for better hands-on experience (fabrication training, makerspace access, supplied materials) and outcomes?

Conceptual Framework

Facilitating learning in introductory engineering design is enhanced when students are intrinsically motivated to strive for high-quality outcomes [3]. Intrinsic motivation plays a critical role in engineering design courses because it supports higher levels of engagement, persistence, and creativity, which are essential for solving open-ended engineering problems. When students are driven by genuine interest and internal value, they are more likely to engage in deeper learning and sustain effort over time, which is particularly important in engineering where innovation depends on curiosity and autonomy. Research across motivational frameworks demonstrates that intrinsic motivation is strengthened when students believe they can succeed at a task and see value in it (Expectancy–Value Theory) [4], when they adopt mastery-oriented goals that emphasize learning and improvement (Achievement Goal Theory) [5], [6], [7], and when classroom environments support students' autonomy, competence, and relatedness (Self-Determination Theory) [8]. Within engineering education, strategies known to enhance students' intrinsic motivation include allowing students to choose project topics, grounding assignments in authentic, real-world problems, providing scaffolding with clear milestones and feedback, and using team-based projects that incorporate peer mentoring. Because engineering design is fundamentally collaborative, team motivation also plays a significant role. Highly motivated teams are more likely to exceed performance expectations and demonstrate stronger design outcomes in engineering design courses [9]. These factors highlight the importance of intentionally designing design courses that cultivate intrinsic motivation at both the individual and team levels.

To more clearly interpret how instructional decisions support intrinsic motivation, it is helpful to anchor this discussion in Self-Determination Theory (SDT). SDT provides a useful lens for understanding student motivation in engineering design [8], [10]. SDT posits that intrinsic motivation is strengthened when learning environments support students' autonomy, competence, and relatedness [11]. Design courses naturally engage these needs when students have meaningful ownership of their work, receive scaffolded opportunities to develop capability, and collaborate within supportive peer structures [12], [13]. These motivational constructs guided our redesign: the multiclient model was intended to increase autonomy through differentiated client needs, competence through iterative prototyping and structured feedback, and relatedness through studio-level collaboration and cross-section interaction. Building on this SDT framing, we consider how features of engineering design courses, particularly those known to enhance motivation, align with or challenge the satisfaction of autonomy, competence, and relatedness.

Research in engineering education has shown that motivation increases when learning environments incorporate elements that are engaging, competitive [14], hands-on/project-based, and personally meaningful for students. However, incorporating these at scale, for large design courses, presents many time intensive difficulties:

- Instructor feedback: No single "correct" solution, making assessment less objective and feedback less consistent.
- User feedback: Students need to interface with stakeholders to develop customer-focused design skills.
- Sourcing and scoping projects: Constrained enough to be meaningfully challenging, open-ended enough to allow creativity and varied approaches, and tractable enough to make meaningful progress within the course timeline.
- Physical prototyping: Workspaces and training for students need to be provided that include access to basic tools and materials.

When all teams receive the same narrowly defined prompt, students often converge on similar solutions, decreasing motivation and limiting opportunities for authentic peer critique. Conversely, when every team has a unique project, assessments can become less equitable, class-wide guidance becomes harder to tailor, and the variety of supplies and materials that may be needed leads to further cost, space, and organizational challenges.

Course Context

At our institution, students used to take ME 395, Introduction to Engineering Design, at the end of their junior year or the start of their senior year. The course follows a 10-week quarter system plus finals week, and covered topics such as formulating requirements and specifications, ideation methods, and applying design frameworks such as universal design and engineering economics. It was lecture-based, so any design projects in the course could realistically only reach a preliminary design phase on paper and in CAD. Student evaluations were low (approximately 30% satisfied) and only 35% said that it prepared them well for their capstone project. The department was experiencing significant growth in enrollment, forecast to increase from approximately 40-120 for this course to over 220 graduating seniors each year.

To address these challenges, the course was fully redesigned to better support student learning at scale. The ME 395 course was restructured as ME 493, Introduction to Capstone Design, which all students take in the first quarter of their senior year, immediately preceding their two-quarter capstone design project course. Students enter the class with diverse prior experiences in engineering design, engineering analysis, prototyping and teamwork and making it essential to create a course structure that provides both a shared foundation and opportunities for differentiated learning through hands-on practice. The main top-level learning objectives were 1) devise a solution that meets a desired need by applying an engineering design process and 2) collaborate effectively on a diverse team in a professional environment with a variety of stakeholders.

Over the course of the quarter, students work on a project to complete a full engineering design cycle. The course uses a dual format weekly cadence:

- One 80-minute large lecture attended by the entire cohort (split on 2 sections, to accommodate university space availability), focused on introductory design skills and theories as well as professional and technical communication.
- One 80-minute studio session, capped at 24 students per section, where teams engage directly in hands-on design activities, prototype development, and structured peer review.

Studios play a central role in the course, serving as the primary environment where students apply lecture concepts to their ongoing project and get feedback from the teaching assistant leading the section. The smaller studio setting supports collaboration and iterative problem solving, which are conditions necessary for students to progress through a complete design cycle within the quarter. Each studio is equipped and scheduled to facilitate activities such as need finding, concept generation, low fidelity prototyping, subsystem testing, and preparation for design reviews.

In the first iteration of this new course, autumn 2023, all teams were given a common design prompt. The solution space ended up being too narrow, opportunity for client-engagement was limited, and student course evaluations were poor, calling for significant improvements.

In the next iteration, autumn 2024, the design prompt and format were revamped into a new project structure that is the focus of this paper. This format was repeated in autumn 2025 with minor improvements. This most recent iteration had 220 seniors and was co-taught by two professors. There were 9 studio sections, each with 6 teams of approximately 4 students, for 54 teams in total. The professors led the first studio section and four graduate teaching assistants led the other 8. The studio space had a modest selection of hand tools and common low-fidelity prototyping materials and ten 3D printers, and students had key-card-access to the space outside of studio times, after completing basic safety and equipment trainings. The space and equipment were managed with the help of two part-time (graduate student) technicians, who also facilitated student access to laser cutters in a separate makerspace.

A Novel Design Course Project Structure

To balance the challenges of student motivation, customer engagement, and facilitating fabrication in our large course, we restructured the course with a common design prompt and several real-world "clients" with distinct needs. Within each studio section, every team is assigned a different client and tasked with designing a response to the prompt that is customized for their client. This ensures that each client appears only once per studio section but is used across multiple studios. Because each client has unique requirements for the same product, students within the same section are encouraged to collaborate and give meaningful feedback through structured peer design reviews, while teams between the sections are in friendly competition to see who can submit the design that their shared client likes the most.

The common design prompt was structured as a request for proposal, an RFP, from a fictitious company who specializes in providing custom designed devices for their clients. For clients, we enlisted staff and other faculty from the university, with the company's specialty being reimagined candy bowls: "a fun and engaging way for faculty and staff to offer a treat to students and visitors so they feel welcomed, relaxed, and ready-to-learn." Each studio section was treated as a design firm with several individual teams, each developing a functional device for a different client (Figure 1). Each client would receive a submission from each design firm and be able to select their favorite device at the end of the course to keep in their office.

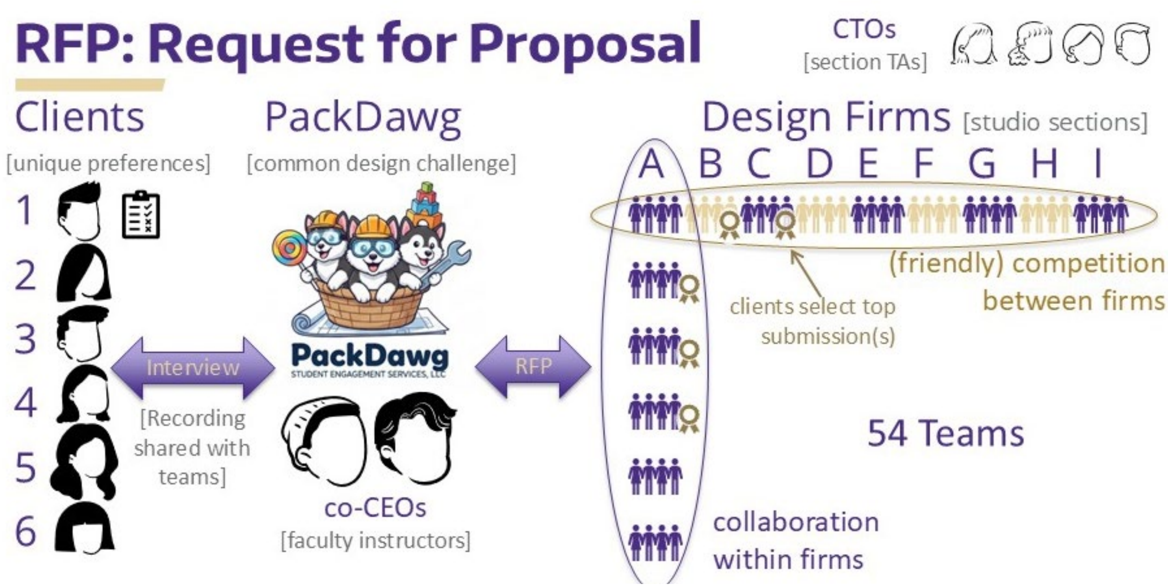

Figure 1: The design challenge for a large introduction-to-engineering-design course structured as an RFP with a common design challenge and several real-world "clients" with unique preferences, supporting collaboration within studio sections and competition between them.

All teams were working on a similar type of device, so they could be provided with similar prototyping suppliers, materials, equipment, and guidance. High level requirements and specifications could be provided for all teams, such as constraints on budget, size, and food safety, and key-performance-indicators (KPIs) such as capacity and time-to-refill. Yet each client wanted something different. For example, the renewable energy professor wanted something that features the engineering topics he teaches and allows students choice; while a staff who is a part-time artist wanted Hi-Chews offered in a device that featured color and whimsical. Each student team had to develop additional requirements based on a recorded video of the instructors performing a needs-assessment interview with their assigned client. This combination of consistent high-level and client-specific requirements allowed for a lot of creativity while still imposing real constraints and the practical challenges of developing a functioning device with moving components for their final deliverable.

Milestone deliverables were structured into the course project: system requirements review with a problem definition, preliminary design reviews with “0th” prototypes, strategic prototyping with alpha prototypes, critical design reviews with beta prototypes, and a culminating pitch with the final product.

To support physical prototyping, workspaces and training for students were provided. This included access to basic tools (scissors, hot glue guns, etc.), fabrication equipment (3D printers, laser cutters, drills, etc.), and materials (cardboard, PLA filament, acrylic and plywood sheets, extruded aluminum beams, brackets, and fasteners, etc.). All students had completed a prerequisite CAD course and most students had completed our machine shop course. Some additional training videos and guides were provided, as well as staff-supported access times for the laser cutter. A selection of popular materials and supplies were provided, as well as a “cost sheet” so students could calculate the BOM (bill-of-materials) for their final design. Students were allowed to purchase up to $50 of additional materials on their own. Example completed candy bowls that the students designed and fabricated are shown in Figure 2.

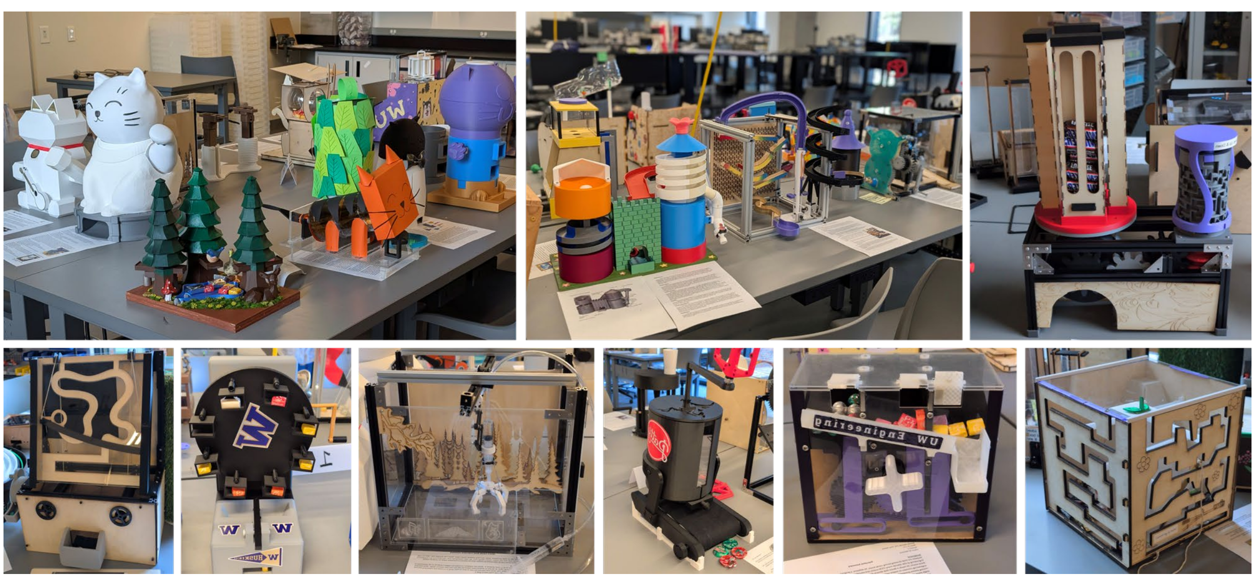

Figure 2: Students designed and built interactive "Reimagined Candybowls" for specific clients.

The students participate in multiple peer design reviews during this course. Two short, informal reviews were done for systems requirements and alpha prototyping, and two formal reviews were done for preliminary design and beta prototypes. In lecture, students were introduced to the concept and importance of design reviews in current engineering practice alongside different aspects of design reviews in engineering design, such as how to give effective technical presentations and providing actionable feedback. For example, the preliminary design review was structured as an 8–10-minute presentation, which was shared with peers as a prerecorded video (in the first two years) or presented live during a studio section. Clear instructions (direction, questions and rubric) were provided on the expectations and outcomes of the presentation. Subsequently, each team member individually examined their team's work as well as the projects of two other assigned teams according to rubric and instructions. During design reviews, reviewers were tasked with rating the work, providing feedback and asking thoughtful questions, while maintaining professionalism and objectivity. These ratings served purely as constructive, formative feedback rather than affecting official grades. After receiving reviews and feedback, each team evaluated their own work, discussed the feedback collectively, and incorporated useful feedback in their design.

To reduce the time demands of the clients, the only interim feedback provided was the preliminary design review. Design teams shared their presentation slides and clients filled in a simple rubric and a few sentences of comments. The final pitch was made in-person to the client and competing teams from other sections.

Multiple strategies were employed to support equitable team outcomes [15]. Teams were formulated by the instructors, not self-selected, with some accommodation of students' preferences for which client to work with and a classmate they wanted to avoid working with. Students were instructed to not contact the clients outside of the structured preliminary design review. Feedback from the client was supplemented with feedback from studio instructors (teaching assistants). The studio instructors met weekly to share their observation and calibrate the feedback and grades they were providing. Teamwork peer evaluations were facilitated during the project, with follow-up coaching or conflict resolution support for struggling students.

Several targeted revisions were implemented this year (autumn 2025) to address challenges from the previous offering. Most notably, teams now generate their own requirements and specifications from client interview videos rather than relying on instructor-provided requirements, strengthening their user-centered design skills. The milestone sequence was adjusted to encourage earlier and more iterative prototyping, including an earlier project start, low fidelity subsystem prototypes at the conceptual design review, and additional time for integration before final fabrication. A round of client feedback was added to the preliminary design review, and final deliverables were updated to include a live client pitch and a concise executive summary.

Methods

Formal evaluation of the main goals of this redesign is in development, but several methods were used for the initial assessment presented in this work-in-progress paper:

- The university's standard course-end student evaluation forms for project-based courses. These use open-ended and Likert-style questions. The university adjusts the reported statistics to equate classes on reason for students taking the course, class size, and grading leniency, all of which are correlated with rating results.
- An instructor-facilitated capstone program survey administered at the completion of the capstone project in June. This uses open-ended and Likert-style questions, focused on areas such as satisfaction with aspects of the courses, their project, and the overall program, their experiences in the program, their learning outcomes, and the resources and support available.
- An instructor-facilitated mid-quarter feedback survey with responses via a Likert scale (1: strongly disagree, 5: strongly agree) administered part-way through the course (in autumn 2025).
- Informal feedback from clients, as part of various conversations with the instructional team during and after the course.

All student responses were anonymous. All activities involved commonly accepted educational settings and normal education practices, and all surveys were implemented for internal program evaluation only, so are excluded from Institutional Review Board (IRB) review requirements. Future surveys exploring questions that could better contribute to generalizable knowledge will be submitted for IRB determination or review.

Preliminary Results

A summary of results from the student surveys is presented in Table 1. Overall, in the first year of this new design prompt structure, evaluations for the course as a whole increased 25% from the prior year (which had used a more closed-ended prompt without this multi-client approach). In the follow-up survey at the end of their capstone program, a significantly higher number of students reported greater satisfaction and intellectual stimulation with the open-ended, multi-client prompt than previous year's closed-ended, single-client prompt.

Clients were very impressed by the creativity and quality of the final devices, and several reported difficulty selecting a single favorite, instead asking to keep several for their office. One client reflected on the design process as follows:

"I enjoyed seeing multiple design approaches to the same request and how teams refined their ideas over successive iterations. My favorite design was one I had never imagined when I first described my criteria."

Open-ended responses in end-of-course evaluation in autumn 2024 were coded to identify trends: 33% of students mentioned the course was intellectually stimulating and 53% (20 out of 38) students indicated the studio section, project, or hands-on activities contributed most to their learning. It is important to note that a limitation of comparing the surveys from first year of this new project structure (autumn 2024) with the prior year (autumn 2023) is that they conflate the change in the design project structure and a change of the design challenge itself.

Table 1: Summary of the course evaluation of the course (evaluation scale: 0 - Very Poor, 1 - Poor, 2 - Fair, 3 - Good, 4 - Very Good, 5 - Excellent). Asterisk (*) means that the question was open-ended.

Academic Quarter	**Autumn 2023**	**Autumn 2024**	**Autumn 2025**
Prompt	Closed	Open	Open
Client	Single	Multi	Multi
Evaluation Score	2.9/5	3.4/5	3.7/5
Response Rate	36% (63)	28% (50)	50% (110)
Total number of students	173	177	221
Percentage of students dissatisfied with ME 493 after their capstone project completion	53%	14%	collecting June ‘26
Students agreed that ME 493 prepared them well for their senior capstone	35%	65%	collecting June ‘26
Number of students who identified the course as intellectually stimulating *	~12% (6/50)	~33% (13/39)	~15 % (16/109)

Discussion

We do not yet have specific or measurable assessments regarding the three main goals, as work on these is in progress. However, we can share some insights based on the preliminary results. Overall, the initial assessment by the instructional team is that the structure of the design project (a common design prompt with unique clients reused between studio sections to facilitate both collaboration and competition) was mostly effective in achieving the three main goals: (1) enhance student motivation, (2) strengthen customer-focused design skills, and (3) make facilitation feasible at large scale. Most students engaged well with the premise of the design prompt and seemed motivated to do their best work. Having a specific client for each project allowed instructors to provide feedback that refocused the designer’s attention on the individual user and underlying need. Similar technical approaches and challenges across the teams enabled the instructional staff to provide more targeted materials, examples and advice.

To more clearly understand why these effects emerged, we interpret these observations through the lens of motivation frameworks. The multiclient structure appears to support autonomy (students independently interpreting client needs), competence (scaffolded prototyping and iterative reviews), and relatedness (studio-level identity and cross-section interaction), aligning with Self-Determination Theory. This theoretical alignment helps explain the notable increase in student engagement compared to prior offerings.

For example, even though being selected as the client's favorite at the end of the quarter had no impact on a student's grade and provided no benefit beyond "bragging rights", many students went above and beyond to develop a design they hoped their client would select. During the peer feedback portion of their preliminary design review studio, reminding students that they were not competing with their classmates within the studio, but rather working together as a design firm to have all of their submissions selected, dramatically shifted the tone of their feedback from simple critiques to supportive suggestions. A team's project grades were mainly focused on their design process and the effectiveness of their communication, with only a small portion based on design performance (such as satisfying the threshold critical specifications). This seemed to help reduce student stress and allow reasonable design risks.

The focus on an individual client did allow an increase in user-centered design discussions. It was not practical to allow each team to interview the client themselves, but they were exposed to modeling of how an informational interview can be conducted and had to grapple with how to concisely summarize the most important needs of a client, formulate customer requirements without implying a solution, and selecting engineering specification targets and thresholds that facilitate tradeoffs. During detailed design phases and prototyping, when faced with an unexpected challenge, such as a mechanism that did not work as well as they planned, design coaching could refocus the team's attention from the technical challenges of a specific mechanism to solutions that might be simpler but still meet the underlying need of the client. The specific candy bowl prompt also facilitated user-centered design discussions, such as how to make a device intuitive to a visitor through the use of signifiers and affordances, or universal design principles, such as tolerance-for-error. Anecdotally, students also learned to appreciate the importance of clearly communicating a conceptual design graphically for an audience seeing them for the first time, or who may not have a technical background, in order to get helpful feedback.

Having a common design prompt did allow some aspects of the course to be administered more effectively, given the size. Students' information gathering could be seeded in lecture with examples from other industries that they could draw inspiration from. The instructional team could identify trends across teams and share advice more broadly that applied to many others. A set of key performance indicators, KPIs, could be established to benchmark objective performance across all devices, such as refill time, candy capacity, reliability rate, and overall size. Outcomes for teams with a client that had a more challenging request could still be calibrated against the eight other teams with the same client. Coordinating the informational interviews, preliminary design feedback, and final pitch schedules for six individual clients was still challenging, but certainly easier than if there had been 54.

Summarizing the preliminary results and discussion as they pertain to the initial research questions:

- RQ1. *Does the new structure improve students' perception of the course as valuable and their intrinsic motivation to engage with their design prompt and their peer design reviews?* The anecdotal experiences of the instructional team and improvements in survey results suggest that yes, the structure is beneficially increasing these areas.
- RQ2. *Does the new structure increase perceived preparedness for capstone relative to the prior structure?* Our end-of-year survey from the first new implementation shows substantial positive increase in the "preparedness" question, suggesting the affirmative.
- RQ3. *Does the new structure allow for better hands-on experience (fabrication training, makerspace access, supplied materials) and outcomes?* Challenges here remain and continued refinement will be needed, but our initial assessments are that it is promising.

Remaining Challenges and Future Work

Management of the studio space was still challenging, but the common design challenges allowed us to anticipate the types of materials, supplies, and fabrication methods that most teams would find useful and stock these successfully. The studio was stocked with a limited subset of supplies, such as 15x15 mm MakerBeam and 1x1 inch 80/20 extruded aluminum beams pre-cut to 3 different lengths, and plywood and acrylic of 2 different thicknesses, but this still facilitated a lot of design freedom and meaningful trade-offs—especially with the 3D printers. Part way through the course, additional items were added that multiple teams had requested, such as flexible tubes and thermoformable sheets. The students were able to implement significantly more advanced technical fabrication techniques than in prior years, which we determined supported the learning outcomes.

Although the results are promising, the present outcomes and results are initial and moderate response rate in course assessment. Despite positive qualitative assessment, the results are limited by statistical data. In future, more criteria could be added in the course evaluation to assess the effectiveness of the course in terms of students' individual and team-wise achievements. Following are some examples to be measured on a scale of 1-10 to evaluate the effectiveness of the course: a) how effective the course was in understanding the design process, b) how effective the course was in developing team-work and collaboration ability, c) how effective the course in improving technical communication, d) how effective the course was in enhancing creativity with known constraints, etc.

The collaborative/competitive design project structure could be transferred to other contexts where it may also be beneficial. The premise of the design challenge, a reimagined candy bowl, could be adapted to something more aligned to a course's learning objectives, students' technical background, or the fabrication facilities available. The scope of the deliverable could be adapted from a ready-to-use product to, for example, a preliminary design proposal or a minimum viable product. The clients for the project could be adjusted to be any variation of users that the instructional team may have access to. An AI agent, perhaps seeded with the transcript from the information interview, could possibly facilitate a limited opportunity for students to practice their own needs assessment. Finally, the pacing and structure of the milestone deliverables could also be adjusted to fit the learning objectives and term length.

Future work will focus on refining the client structure, milestone pacing, and design prompt, while gathering more systematic data to understand the effectiveness of the multiclient model in achieving our original three restructuring goals and its impact on student learning. The instructional team plans to implement targeted student surveys to better evaluate how the course structure influences design skills, intrinsic motivation and collaboration. Additional areas of investigation include how implementation decisions, such as the peer review format and opportunities for client interaction, shape the learning environment in large courses, and how the model might be adapted for other disciplines or contexts with different resources, client types, or instructional goals. Specifically, we propose the following future research questions:

- FRQ1. Does the multiclient structure improve students' intrinsic motivation to engage with the course?
    a) Do students perceive the design outcome as valuable (to the client and users)?
    b) Do the students perceive the design process as valuable to their learning (developing competence for their capstone)?
    c) Do students perceive autonomy in the design space?
    d) Do students perceive a connection to others on their team and their section (relatedness)?
    e) Do students perceive the peer design reviews as useful?
- FRQ2. Does the multiclient structure improve students' customer-focused design skills?
- FRQ3. Does the multiclient structure improve the logistics of providing meaningful design experiences in large courses?
    a) Is makerspace access and support (training, access, supplies) simplified?
    b) Is client management tractable?
    c) Is feedback, assessment, and evaluation of the design projects more equitable?

Conclusion

This Work-in-Progress paper presents a scalable multiclient project structure designed to improve motivation, authenticity, and logistical feasibility in a large introductory engineering design course. By pairing a common design prompt with distinct real-world clients and integrating structured peer review within studio sections, the course creates opportunities for meaningful collaboration, friendly competition, and deeper engagement with user-centered design. Early results indicate promising improvements in student motivation and clarity of expectations compared to prior course iterations. As we continue to refine the structure, future work will focus on more rigorous assessment of student learning, the impact of peer review practices, and the transferability of this model to other disciplines and institutional contexts.

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