

# INTEGRATING EXPERT DESIGN REVIEWS IN PROJECT-BASED DESIGN COURSES TO ADDRESS MULTIPLE LEARNING GOALS

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## ABSTRACT

We present how conducting expert design reviews in an undergraduate, capstone design project course can address learning goals related to design, communication, and professionalism. In this course, student teams work on client-based, open-ended projects. At two points in the process, each team participates in a design review that is held outside of class, using external experts with real domain knowledge. External reviewers are critical as they: are able to apply deep domain-specific knowledge and design experience to the project challenges, reinforce the model of the design process that we teach, add credibility due to their status as design professionals, and detect weaknesses in the designs. Having outside experts also emphasizes the coaching role of instructors, as they are no longer the main audience that the team must inform and persuade. Prior to the review, students write a design brief that is required to be concise, easy-to-skim, focused on evidence-based decisions, and supported with appropriate visual elements. They also prepare and practice a short presentation aligned with the design brief. During the review, they give the presentation, use interpersonal skills to solicit feedback and guide the conversation, take detailed notes, and sketch concepts to support discussion. Our experience suggests that implementing structured design reviews with well-qualified design professionals can catalyze student achievement in project-based design courses. In addition, when the design review experience includes a series of pre- and post-review design and communication activities, it creates a common thread throughout the course that links the learning goals.

*Keywords: Design reviews, design process, communication, teamwork, learning goals.*

## 1 INTRODUCTION

Design reviews are a critical element of the design process in a wide range of industries. There is abundant information on stage-gate reviews that focus on go/no-go decisions to move forward. Stage-gate reviews are conducted from the point of view of making a judgement. Reviews of this type are frequently used in capstone design courses in undergraduate engineering curricula [1, 2, 3]. Like those in industry, these design reviews also focus on judgement or decision making, and are often used as a checkpoint [4, 5, 6, 7]. Duesing et al. [4] describe the “focus of the design review is to reach key conclusions and decisions upon which the customer and the student team mutually agree.” Moore et al. [5] describe a series of critical design reviews where two or more faculty members are “encouraged to ask questions and provide suggestions following a brief oral presentation by a randomly selected member of the project group.” In contrast, design reviews as discussed in this paper are focused on improving a design. The review structure used in the course is based in part on the personal experience of the faculty who have conducted design reviews in industry in companies like IDEO, and input from the reviewers who themselves conduct design reviews in their own work.

In his book, *Creativity, Inc.*, Ed Catmull describes the makeup and function of the Braintrust, which is an exact parallel of the design review process we discuss [8]. Catmull describes the Braintrust as “a forum that ensures we raise our game – not by being prescriptive, but by offering candor and deep analysis.” The two factors that make it so profoundly successful are that it is “made up of people who have a deep understanding of storytelling and, usually, people who have been through the process themselves,” and that “the Braintrust has no authority.” After a Braintrust meeting, the director must decide on their own how to move forward.

We follow this model of design review in our interdisciplinary design course sequence. This undergraduate sequence is taught within the engineering school, but is open to third- thru fifth-year students of any discipline who have completed a prerequisite introductory course on user-centered design. The class tends to be roughly two-thirds engineering students and one-third from other disciplines. Students work in small teams on open-ended design projects, each with a different external client. The goal in each case is to create a functional prototype that meets client and user needs. The projects last approximately twenty weeks, spanning two academic quarters. Two formal design reviews with three to five external reviewers, most of them industry experts, punctuate the design process: the first takes place in week eight of the first quarter; and the second takes place in week five of the second. In this paper, we focus on the first quarter review. Below are two examples of past projects, showing the students' disciplines and the areas of expertise of the reviewers.

*Table 1. Examples of recent project teams and reviewers*

Project Goal	Student Team	Expert Reviewers
To redesign the dishwashing experience	<ul style="list-style-type: none"> <li>• Manufacturing &amp; Design Engineering, senior</li> <li>• Manufacturing &amp; Design Engineering, junior</li> <li>• Mechanical Engineering, junior</li> <li>• Social Policy, junior</li> </ul>	<ol style="list-style-type: none"> <li>1. Industrial designer at a design consulting firm</li> <li>2. Human factors engineer at a medical device company</li> <li>3. Mechanical engineer at a consumer goods company</li> <li>4. Product designer at a design consulting firm</li> </ol>
To provide uniform, high intensity illumination to a custom-built cell stretching device in the lab	<ul style="list-style-type: none"> <li>• Manufacturing &amp; Design Engineering, senior</li> <li>• Biomedical Engineering, junior</li> <li>• Mechanical Engineering, junior</li> <li>• Computer Engineering, junior</li> <li>• Computer Science, junior</li> </ul>	<ol style="list-style-type: none"> <li>1. Material scientist and engineer at a sensor technology company</li> <li>2. Mechanical engineer at a design consulting company</li> <li>3. Program director and user centred design instructor at Northwestern University</li> <li>4. Professor of mechanical engineering and mechatronics at Northwestern University</li> </ol>

The fact that the reviewers come from outside the framework of the course is valuable for several reasons. First, they bring to the students' problems deep domain-specific knowledge, as well as significant design experience. Second, they reinforce the model of the design process that we teach, and give it additional credibility because of their status as design professionals. Their remarks carry a great deal of weight with the students. When the remarks reinforce advice they have already heard from multiple sources (course readings, lectures, and instructors' comments), students are more likely to act on the advice. Third, the fact that the reviews are external events, rather than conducted during class, makes them more real, and overcomes the limitations of design reviews that are mere exercises. Fourth, the reviewers are good at detecting weaknesses not only in the teams' designs, but also in their preparation. The reviewers are quick to point out shortcomings in the teams' research and their understanding of the problem.

Finally, recruiting outside experts to participate in the design reviews puts the instructors in a different role: the coaching element is emphasized, and the instructors are no longer the main audience that the team must inform and persuade. Prior to the design review, instructors help the students frame their statements to this new and unknown audience. During the review, they are present but silent, witnesses rather than participants. After the review, they help students process what they heard and learned, and give feedback on the teams' goals and plans, and on their effectiveness in managing the review.

Our experience suggests that the first-quarter design reviews are crucial to the teams' progress towards a high quality design concept, and to students' achievement of multiple learning goals. The design review, including the assignments before and after it, accelerate the students' design process, harness the teams' early research and ideation, expose strengths and weaknesses in teamwork, and demand that students set and achieve specific goals for professional communication.

We present here an overview of the design review process used in the course, a summary of how the assignments are integrated and serve learning goals, and a discussion of the resources required to support the reviews, especially a network of willing and suitable expert reviewers.

*Table 2. Overview of the design review process used in the course*

Prior to review	Teams submit a written design review brief that is sent to the reviewers one day in advance, and prepare a short presentation. Both are revised with feedback from peers and instructors. Both documents need to present the design concept(s) the team has developed, as well as a concise summary of their research, testing, and analysis, and their plan for the next stage of the project.
Scheduling the review	The reviews are scheduled late afternoon and early evening to accommodate reviewers' schedules. The reviews take place on campus, in a room configured for group discussion around a table. Food and beverages are available.
During the review	Each team spends an hour with the reviewers. Fifteen minutes are devoted to the presentation, and the remaining time is spent in discussion. The teams lead the discussion, and they are responsible for keeping the review focused on the areas of concern that the team has identified. Instructors are present, but as observers in the background rather than participants around the same table.  During the discussion, the reviewers and students exchange questions and ideas. The reviewers frequently make quick sketches to illustrate an idea, or examine physical mockups brought by the team. The pace is rapid, and the students take copious notes. The instructors also take notes, and prepare feedback for the teams on their effectiveness in the review.
After the review	Teams write a summary and an action plan. They meet with the instructors the following week to discuss the results and receive feedback. They write thank you notes to the reviewers, and may ask them further questions or schedule follow-up meetings.

## **2 INTEGRATION OF THE DESIGN REVIEW BRIEF AND PRESENTATION WITH OTHER ASSIGNMENTS**

The design review brief and presentation address both small- and large-scale learning goals in the course, and are integrated with earlier assignments. For example, design concepts covered in readings and lectures (e.g., human factors, robust design, and sustainability) are expected to be addressed in the students' current work and future project plans.

The same is also true of learning goals in communication and teamwork. For example, in-class exercises on writing effective topic sentences and designing effective slides feed directly into the preparation of the brief and presentation. Moreover, preparing the brief and presentation require the students to understand their purpose and audience. Because the reviewers are not already familiar with the project, the briefs and presentations must be both concise and evidence-driven, and must include effective and appropriate visuals.

A key feature of the reviews is that they are led by the student team. Only in rare instances will faculty step in to provide guidance during the review. Students must take charge of guiding conversation and be willing to steer the reviewers. For example, it is important for teams to recognize when to stick to their agenda versus allowing the conversation to go in an unanticipated direction, and to judge how long they should allow that conversation to continue. In preparation for the review, students practice techniques for respectfully acknowledging reviewer comments and moving to a new topic.

The assignments following the review continue to address multiple goals. For example, in creating the summaries, the teams must translate their raw notes into an organized document that they can later reference as they explore ideas and support decisions. Prioritizing next steps into an action plan, reviewing this plan with faculty, and updating their Gantt charts helps ensure that the leads generated by the review are followed, and that nothing important is omitted.

Even in something as small as writing thank-you notes to the reviewers, teams practice techniques for building goodwill in business relationships and techniques for asking questions and making requests in a way that makes it easier for reviewers to respond. These combined assignments help teams make sense of what they learned in the review, and prepare to move forward.

We have found that the timing of these assignments and the reviews are important. Over the years, we have experimented with where to place the design review in the first quarter. When the review took place in the final week of the quarter, teams did not have adequate time to process the results of the review before the break, and it took longer for them to get re-engaged when they returned for the

second quarter. However, placing the review at the midpoint of the quarter did not provide adequate time for preparation. Holding the reviews at week eight of the ten-week quarter allows time for the teams to make enough project progress for the reviews to be useful, as well as enough time afterwards to begin making progress on their plans.

### **3 INTEGRATING EXPERT DESIGN REVIEWS REQUIRES RESOURCES**

To integrate expert design reviews into our course, several key resources must be present. The most critical resource is the network of professionals. Over the past twelve plus years, we have worked to create this network by building relationships with local design firms and engineering companies. We have identified high performing reviewers, supplemented by members of the faculty who have experience both doing and teaching design.

Many of our reviewers have experience in product development or manufacturing across a range of industries, and their breadth of expertise makes it possible to find reviewers for a wide range of project types. It is also beneficial to have a stable pool of reviewers to provide continuity across reviews, and allow the reviewers to build a community of their own. Many reviewers enjoy the networking and interactions with each other as much as they enjoy working with the students.

The table below breaks down the reviewers for this past year's reviews by type and by time, and demonstrates the extent of our reliance on industry professionals, as well as the importance of bringing back good reviewers. The majority of our reviewers are design professionals, either in engineering design or in another design field. Most have served on reviews for more than five years, with only three new reviewers added this year.

*Table 3. Design review pool composition, academic year 2016-17*

	Design Faculty	Design Professionals	Engineering Design Professionals	Total
<b>Size of DR pool</b>	<b>6</b>	<b>22</b>	<b>6</b>	<b>34</b>
Reviewers in DR pool over 5 years	5	14	1	20
Reviewers in DR pool 2-4 years	1	6	4	11
New reviewers	0	2	1	3

Selecting and cultivating new reviewers is something we prefer to do slowly. In addition to reviewers with relevant expertise, we also seek out reviewers whose personalities make them effective mentors, so that they can be both firm and patient when working with undergraduates. It can take participating in several reviews before a reviewer is able to judge whether a team is well- or poorly-prepared at this stage, and what advice would best reach them. New reviewers are typically invited to serve as a fifth, supplemental reviewer, so they have a chance to observe the interactions between the reviewers and students, and can develop a benchmark for future reviews.

Facilities and catering are also important resources. Setting the right tone for the review requires a design studio space that has work tables that can be grouped into a larger conference-room style table. Design studios typically have plenty of space to allow prototypes in the room, a separate table for food, and space for the reviewers to mingle at the start and end of the reviews. The food is important. We want everyone to be comfortable at the review, and we want to emphasize that this is a special event. Since the reviewers are likely to be coming straight from work, we provide a variety of hearty and healthy snacks that include at least one vegetarian protein option.

### **4 DESIGN REVIEWS PROMOTE BETTER DESIGN PROCESS AS WELL AS BETTER DESIGNS**

Design reviews play an important role in improving the quality of the design itself, and in helping students to become grounded in the design process and the role of reviews, to gain exposure to the design industry, and to be motivated to achieve more before going into the review. The fact that the external expert reviewers are not gatekeepers means that the conversations are more open-ended. As Adams et al. [9] point out, experienced reviewers often “encourage students to make their own informed design decisions” rather than explicitly telling students what to do. Daly and Yilmaz [10]

identify examples of design review feedback that “allow students take either a convergent or divergent approach moving forward,” noting especially the importance of encouraging the latter, through “suggestions to explore ways they could accomplish an idea” and “multiple options for the students to consider.” Divergent questioning is vital to design, as discussed in Dym et al. [11], who note that “[t]eaching divergent inquiry in design thinking is neither recognized clearly nor performed well in engineering curricula.” We submit that our style of reviews encourages students to practice divergent inquiry because the reviewers demonstrate it for them, and participate in it with them.

During the review, the students hear how professional designers and engineers talk about design, including the vocabulary they use, the topics they stress, the details they consider, and the actions they suggest for moving forward. The emphasis we place on including compelling evidence for decisions leads teams to conduct more research, testing (user and performance), and engineering analysis. As faculty work with the students on how to communicate their design and engineering work through the design brief and presentation, we are able to identify gaps in their process or in their knowledge while there is still time to address some of those gaps before the review.

The reviews create accountability for students’ work. If a team glosses over an aspect of the design, or doesn’t provide compelling evidence for their design decisions, the reviewers point it out. In some cases, it may be that the team simply hadn’t presented those details and just needs to provide the appropriate information in response. In cases where a team hasn’t done the work expected by reviewers, a reviewer may emphasize the importance of those activities. Their comments are often similar to those made by faculty to the team prior to the review, but coming from an outside expert imparts greater significance and teams tend to be more responsive. Each of these situations is a learning experience that affects how the team prepares for their second design review.

The first design review is often a turning point in the student projects. Lower performing teams may become more motivated after seeing how professionals react to their work. Higher performing teams tend to get excited by the feedback, new ideas, and sources to explore. Quite often, there is a significant change in the design direction based on the reviewer feedback. Because all teams are required to create an action plan, which they review with faculty in a supervisor-style meeting before moving ahead, they are also required to actively select which advice from reviewers to address first. They need to recognize that not all advice is equally applicable, or even accurate. While the reviewers are experts in some areas, they are not omniscient. The teams must take ownership for validating suggestions they receive, and not simply base a decision on “because the reviewer said so.” In addition, it is not possible for teams to follow all of the advice they receive. They need to prioritize the feedback to take into consideration both the design requirements and the class constraints.

## **5 DESIGN REVIEWS DRIVE HIGHER QUALITY COMMUNICATION**

Teams are motivated to create higher quality briefs and presentations since there is a real need to communicate. Students are accustomed to creating deliverables for the purpose of getting recognition; in this case they need to prepare deliverables for the sake of getting critique. While some teams are able to recognize this difference and create materials that support it, other teams don’t fully appreciate the difference until after the first review, but then tend to better prepare for the second review.

The faculty work with the teams as they prepare their communication deliverables. We emphasize the need to concisely and effectively convey their design, the rationale, and the supporting evidence in order to get useful feedback. To this end, students learn how to use talking headings and slide titles, when to use bullets and tables to make key content easy to skim, and how to craft effective visuals. There are also multiple opportunities for instructor and peer review. One cycle of feedback and revision is built into the required assignments, and teams often request additional feedback as they revise their work.

## **6 DESIGN REVIEWS PROVIDE OPPORTUNITIES FOR MULTIPLE ASSESSMENTS**

The design review is a major milestone for each team. Being adequately prepared for the review, and conducting an effective review, requires good project planning and teamwork, as well as a professional demeanour. This creates an opportunity for faculty to uncover gaps between the team’s planning versus actual progress. Faculty can discuss those gaps with the team and work to identify underlying causes. The integrated design review process also creates several windows for faculty to see what is really happening on the teams, particularly in project management, knowledge sharing, and

the team dynamic. Observing the team during the review can provide insights on how project knowledge is shared among team members, how they interact and support each other, and how they respond to feedback. If one team member dominates the discussion, it is important to identify whether this is a team dynamic issue or whether the other team members are actually less informed on the topics. Both situations should be addressed after the review. Things to watch for in the review include:

- Do they share the discussion and responsibility for responding to questions, or do any of the team members look blankly to someone else to respond
- Do they build on what each other says
- Do they trust each other to answer the questions, or do they interrupt each other and re-state the same information in their own words
- Do they actively guide the reviewers to stay on topic and manage the time
- Do they accept the feedback and ask additional questions, or do they get defensive
- Do they use professional language
- Do they use appropriate technical terms, reflecting their understanding of the engineering and social science concepts

## 7 CONCLUSION

Design reviews are widely used in engineering design courses. Likewise, the need for these design reviews to be informed by industry best practices has often been expressed. However, it can be difficult to create design reviews that overcome the limitations of the classroom setting, and to help students take full advantage of the insights offered at a design review. We believe that our model for staging design reviews suggests how some of these difficulties can be addressed. By cultivating a network of expert reviewers, preparing our students to engage with them, and drawing out the lessons to be learned from that engagement, we have advanced not only our students' design process, but also their professional development.

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