# Enriching Freshman Design Through Collaboration With Professional Designers

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Engineering educators over the last fifteen years have increasingly emphasized the teaching of design.[1] As a result, design courses are not only being offered as a capstone experience in engineering majors; they are increasingly found at the freshman and sophomore level. This latter development has sparked a controversy about whether it is desirable, or even possible, to teach design to freshmen. As Carol McConica explains, in a 1996 edition of *Chemical Engineering Education*, "Freshman design courses are problematic because students do not yet have the fundamental engineering background necessary to solve real problems."[2]

Like many of our colleagues elsewhere, [3] we at Northwestern see freshman limitations as a challenge, but not a roadblock. To meet this challenge, we proposed to develop a freshman course in user-centered design, having students work on real projects for real clients, by learning the design strategies used by professional industrial designers. At Northwestern, we are fortunate to be near the Chicago offices of several renowned design firms—such as IDEO, Herbst LaZar Bell, and the Nielsen Norman Group—as well as the offices of first-rate smaller design companies. By inviting designers from these companies to collaborate with us as co-developers, lecturers, faculty trainers, and classroom teachers, we aim to embody in our freshman course best practices from some of the best companies in design.[4]

Our collaboration, which has increased over the years, has had a major impact on the way we teach design and has greatly contributed to the success of the freshman course. This paper describes the course, explains the role played by our professional partners, details the innovations that they have brought to the teaching of design, and argues that all parties—students, faculty, and the designers themselves—benefit from the collaboration. Northwestern's freshman design course involves all of these people in a high-level design process that fosters excitement about engineering and pedagogy and thus lays a solid groundwork for the detailed design that students undertake in their majors.

## Course overview

Engineering Design and Communication (EDC) is a key part of Northwestern's integrated freshman engineering curriculum, called Engineering First. Engineering First comprises two courses. In Engineering Analysis, students study math and physics from an engineering perspective in a four-

quarter sequence. In EDC, they study design and communication from an engineering perspective. Each sixteen-student section of EDC is jointly taught by a faculty member from Engineering and one from Arts and Sciences. All 380 freshmen take the course, which is taught by engineering faculty from five or six different disciplines. A small core group of faculty from each school work together to set goals, develop a syllabus, plan lectures, design assignments and activities, manage overall course assessment, and facilitate weekly faculty meetings.

One goal of EDC is to communicate the excitement of engineering and thus motivate students to succeed. EDC does this by having students work on real projects for real clients. In the first quarter, after a brief hands-on project that introduces design, teams of three to five students design web sites for campus departments, research groups, student organizations, local schools, and even small businesses. Working on these projects, students are coached in a user-centered approach to design, in which they use various engineering tools and techniques to define the problem, generate alternatives, observe and interview users, build mockups, conduct design reviews, and produce models or prototypes. Projects culminate in three deliverables: a prototype web site, a written report, and an oral presentation. To stress the point that communication is an integral part of engineering, all the communication requirements in this course—memos, progress reports, proposals, drawings, and PowerPoint presentations—stem from the work in design.

In the second quarter of EDC, students use the same design process to work on projects that span a range of problems and disciplines. Projects come from corporations, not-for-profit agencies, entrepreneurs, and individuals. Many of the projects have a social service dimension. In spring 2000 and 2001, for example, EDC teams worked on designs like the following:

- a small roller coaster toy for children with limited mobility (see Figure 1)
- a feeding tube for a child with familial disautonomia, who is unable to ingest fluids normally (see Figure 2)
- an improved cargo carrier for a minivan
- an improved lighting system for a wheelchair user in a residential facility
- a recumbent bike for an amputee
- a convertible single-tip/multi-tip cane
- a portable massage table that is easier to set up than existing models
- an enhanced “spinal trainer” for physical therapists at the Rehabilitation Institute of Chicago

Since one goal of EDC is to help students develop communication competencies, EDC teaches design and communication as interconnected and parallel processes. All the communication that students practice and produce in the course are key elements in the design process. Students learn how to write progress reports and proposals; interview experts and users; conduct team meetings and client meetings; hold informal design reviews and more formal client presentations. In the process, students learn that communication is not just a school deliverable; it is a productive design tool. By having to articulate their design concepts and make an argument for their merits,

students identify both opportunities and flaws in their design, and sharpen their thinking as engineers. Because communication is critical to the success of their projects, students are motivated to learn how to communicate well.

Figure 1: Roller Coaster Project

Figure 2: Feeding Tube Project

In addition, students come to see that design and communication share similar requirements and benefit from similar processes. For example, students learn that iteration is indispensable both to creative design and to clear communication. Furthermore, they learn that both design prototypes and report drafts are routinely subjected to scrutiny from multiple points of view. Similarly, both designs and reports must be measured against user-defined requirements and criteria. Throughout the course, students see that design and communication are interconnected and reciprocal.

EDC can be viewed in more detail at www.edc.northwestern.edu; key course concepts are described in a link from that site, the EDC online Coursepack.

Factors leading to success

Indicators like the following suggest that EDC is a success:

- In our end-of-the-year surveys, typically over half of the 300+ students report that they are "very satisfied" with major course components (section meetings, projects, etc.) and have learned a "tremendous amount" about key course concepts, such as engineering design process, creativity in design, the role of communication in design, making mockups and prototypes, writing proposals, working in teams, and managing projects. This is a strong result for a required freshman course at Northwestern, but typical for EDC.

- Senior design faculty routinely say that reports and presentations in their classes are vastly improved since students have gone through EDC.

- Clients and ABET evaluators have been pleased with the students' work, which has occasionally garnered national attention.[5]

- Other universities, such as the University of Michigan and the University of Toronto, have benchmarked EDC in developing their own design programs. [6]

- The University administration has shown their confidence in EDC by allocating to it 12,000 square feet in the new Ford Motor Company Engineering Design Center.

The core faculty attributes this success to a number of factors, including such obvious influences as good advice from colleagues, [7] small class size, dedicated faculty, our coaching pedagogy, and our large, flexible studio classrooms in a building with adequate computer and machine shop resources. However, a major factor is our collaboration with professional designers, which has had a profound influence on the course.

Once we began to plan EDC, designers from IDEO and Herbst LaZar Bell consulted regularly with our core faculty, presented guest lectures, ran training sessions for us, and taught sections of the course. An international firm, IDEO's Evanston office is near the Northwestern campus. Herbst LaZar Bell (HLB), the nation's largest privately held product design firm, is headquartered in Chicago. Before EDC, both firms were involved with the capstone design courses at Northwestern, as well as with student competitions. Hence, their leading designers were familiar with the Northwestern faculty members developing our course. Their ongoing contributions have been so valuable that we currently hire four to five professional designers each quarter to teach as EDC adjunct faculty each quarter.

The contributions of these designers have enhanced EDC in four areas in particular: *brainstorming, visual communication, human-centered design, and professionalism*.

*Brainstorming.* Generating ideas is a crucial step in engineering design, and brainstorming is a time-honored method for generating ideas. Most design texts offer some advice about brainstorming (see for example, Dym and Little pp 48-49, 140-141; Ullrich and Eppinger 90-91).[8] However, the design firm IDEO has developed a brainstorming approach that research has found to be particularly effective.[9] It makes optimal use of group brainstorming, as contrasted with some methodologies that combine individual and group concept generation. Currently, there are many articles in the trade press that detail the IDEO methodology, and Tom Kelly, the general manager of IDEO, has written a book that provides brainstorming guidance.[10] The method has even been featured on an episode of NightLine with Ted Koppel (February 9,1999).

None of these instructional resources were available, however, when we began our collaboration with IDEO in 1997. We contacted the firm to learn what elements of their successful design

practice we could best incorporate into our course and learned that their approach to brainstorming was much more structured—and at the same time more creative—than ours. We asked IDEO to train our faculty to teach the brainstorming techniques IDEO uses.

At a faculty institute, three IDEO designers led us through a brainstorm based on one of their past projects. After they explained the problem to us—how to create a collapsible, reusable container for collecting lettuce in the field and transporting it to market— we broke into groups of eight, with paper, markers, and an IDEO facilitator. We played a few warmup games (a key element of the IDEO approach) and then participated in a 45 minute brainstorm, following the IDEO brainstorm rules, which are posted on every wall in the EDC Design Studio:

- Defer judgment
- Build on the ideas of others
- Hold one conversation at a time
- Stay focused on a topic
- Encourage wild ideas

Each group generated about one hundred ideas, sketching and numbering them, and posting our sketches on the walls. When the idea generation was over, we reviewed the problem, clustered suggested solutions, and talked about what would come next in the process.

IDEO consultants later taught EDC faculty how to "facilitate a brainstorm" and run facilitation training sessions for selected students from each class. These students, one from each team, facilitate the brainstorm on their team's design project. IDEO provided a written guide to brainstorming techniques, which was distributed to faculty and students, and which greatly influenced our discussion of brainstorming in the EDC Coursepack.

The brainstorming rules have become a cornerstone of the work that students do in EDC; students who begin the course thinking that three or four ideas sufficiently explore the design space end up with brainstorming sessions that produce well over one hundred ideas in an initial team meeting. The IDEO approach to brainstorming helps them release their creativity throughout the engineering design process, communicate early on with sketching, and work more successfully as teams than they would otherwise.

*Visual communication.* As the IDEO approach to brainstorming suggests, product design depends on visual communication in the early stages, as well as the late stages of the process, when a completed design is visually represented in drawings and prototypes. Because EDC focuses as much on communication as design, we are very interested in helping students develop a vocabulary for visual communication and a broad sense of the three key roles played by graphical representation in the design process: visualization, communication, and documentation.

Typical design texts that we consulted briefly mention sketching and early-stage mockups, but they focus on communication toward the end of the design process: detailed design drawings and prototypes (cf. Ulrich and Eppinger, Dym and Little).[8] At the time we were developing EDC, no comprehensive text existed that focused more broadly on the role of visual communication in design. (An excellent text by Lockhart and Johnson was published in 2000, though it is much too detailed to be appropriate for freshmen.)[11] To get this broader sense of how to leverage visual communication throughout the design process, we turned to our professional design colleagues, who have helped us develop approaches to teaching freshmen three forms of visual communication as design tools: sketching and drawing; models, mockups and prototypes; and display boards.

IDEO provided a conceptual framework for understanding the roles that freehand sketching plays at different stages of the design process, delivering a lecture to students on this topic, replete with examples from successful IDEO projects. In one introductory lesson, students use an online tutorial to learn basic techniques. Then in class, they sketch simple Lego models. Finally, students pair up and attempt to build the Lego model using only their partner's sketch as a guide. Once freshmen have a level of comfort with freehand sketching, they are better able to visualize and develop ideas; communicate ideas within the team, to faculty, and to clients; and document the design process and solutions.

Walter Herbst, the founder and chairman of HLB, has helped us extend the role of visual communication to students' work in the machine shop. He stresses the importance of getting students to sketch throughout the course and to bring accurate drawings, with measurements, to the shop. In his section of EDC, Herbst runs a sketching tutorial for students. This year, we plan to encourage other section instructors to implement this same requirement.

Both IDEO and HBL have helped us promote students' use of models, mockups and prototypes as conceptual design tools at various stages of the design process. Engineering design texts typically focus on proof-of-concept models and looks-like and works-like prototypes that are produced toward the end of the process. In teaching conceptual design to freshman, however, we are interested that they have a framework for understanding a range of modeling and prototyping activities—and that they be able to use appropriate representations to achieve specific goals in the design process.

In class, we help students decide what levels and forms of representation are appropriate for specifc projects. We introduce them to a variety of representational forms:

- Proof of concept (bread-boarding)
- Visual mock-ups (foamcore / foam)
- Visual Models (looks-like prototypes)
- Functional Prototypes
- Alphas / Betas

The design firms that we work with have all stressed the importance of building the design and getting it in front of users and the client for feedback. IDEO, in particular, has a number of corporate mottos that reflect the importance of building and testing early in the process, and we have adopted those as themes of our course:

- Just build it
- Test early and test often
- Fail often to succeed faster

To help students develop models and prototypes, we give them instruction in building with foamcore, using a tutorial—Fabulous Foamcore—that IDEO developed for the company's in-house training. Students also work through an exercise designed by IDEO, prototyping a box using foamcore, X-Acto style knives, and hot glue guns. The effect of the workshop is to help students realize that they can easily make mock-ups throughout the design process to visualize and test design ideas. A high percentage of projects now culminate in thoughtfully designed and well-constructed visual models and prototypes delivered by student teams to their clients.

In the work space in any design firm, the walls are covered with sketches, drawings, CAD results, models—visual representations of where the designers have been and where they are now. In a classroom, it is difficult to reproduce this graphically rich atmosphere; however, we have taken strides toward doing so with the help of another professional designer on our faculty, Paul Specht, the founder and head of PBS Design. Last year, Specht had his students create portable foamcore "war boards" for displaying their sketches, storyboarding their ideas, and presenting these ideas during team meetings and meetings with their instructors. This year all EDC students made war boards in the second week of the class, so that each team has its own physical display space (see Figure 3). In addition, we are asking students to prepare a poster for their final presentations, so they will be able to gain additional experience in communicating their ideas by visualizing them to others.

Figure 3: Student Team with War Board

This emphasis on visualization has filled a gap that has bothered the engineering design faculty for quite some time. Don Frey, a professor in Industrial Engineering who was the lead designer on Ford's original Mustang team, has been calling for more visualization instruction for years. Having taught in EDC, Frey now says "We're finally teaching design the way it should be taught."

*Human-centered design.* Our freshmen come to EDC thinking that, as designers, they will be able to generate all the answers to a problem; and if they need to "survey" users, they can simply send out surveys over the Internet. Thanks to our colleagues in design, EDC students soon learn that they need to take a different approach to gathering information about user needs. A good example of how this works begins with Amy Schwartz's lecture on user observations.

Schwartz is a cognitive psychologist from IDEO who specializes in the role that human factors plays in design. The theme of her EDC lecture is that "context in design is everything." She helps students understand that a product has to be more than just a "cool design"; it has to be something that people can and will use in their everyday environments. She urges students to see themselves as ethnographers who observe people interacting with products in their everyday environments. To encourage students to begin practicing their observation skills, Schwartz shows a short video about people trying to purchase a soft drink from a vending machine. Students see users struggle to get the machine to accept a wrinkled dollar bill—or to get their drink out of the machine while they balance a baby or backpack on one hip and bend down to retrieve the bottle. Tall users squat to make their selection or get their change.

Schwartz then asks students to make a chart listing their observations of people's difficulties during the pop machine task, the opportunities for innovation, and some design directions that could take advantage of those opportunities. To reinforce the main points of her lecture, we assign students homework that involves making a similar chart for an observation they do on their own, such as observing people disposing of their trash in a fast food restaurant or finding the right key to get into the dorm. The lecture and homework culminate in observations that students do for their projects. By that point, they have learned the value of observation and look for opportunities to do observations at various stages of their projects: early on in order to understand the problem, and later to evaluate users' interactions with their mockups.

Other designers have helped students develop strategies for conducting effective user interviews. Don Norman, of the Norman/Nielsen group and the author of *The Design of Everyday Things*, has helped us to involve user testing more fully in the design process. One of his key insights is that you can't just listen to what users say, you have to watch what they do. Norman contends that in-depth observations of five key users will provide more useful information than 50 Internet surveys. Drawing on Norman's ideas, this year, after creating mockups of alternative design concepts, we are having student teams devise tasks for their users to perform with the mockups. As users attempt to perform these tasks, the students observe them and make notes on their steps and mis-steps. Students then use that information to develop new designs. Norman has also led

us to include in the course a discussion of "scenarios," stories in which students imagine themselves as potentially real users interacting with a specific web site or other product being designed. Through the use of these scenarios, students gain a better understanding of user needs, including the critical role of social context.

*Professionalism***.** One of the problems posed by a design course for freshmen is the students' inexperience and, in some cases, their immaturity. Even in a project-based course with real clients, many of the students have trouble acting professionally or thinking of themselves as professionals rather than as college freshmen. Some communicate with clients inappropriately or insufficiently. Others run into the design shop shortly before they need a prototype for their design review and expect the shop foreman to be available at their convenience to help them build what they need.

Our professional design faculty have helped us encourage a greater degree of professionalism among our students. This year students are using an EDC business card template to produce cards that they can give to clients during their initial client meetings. Moreover, in one of the early class lectures, a panel of designers discussed successful ways to "launch a project" and communicate professionally with clients, users, and other key outsiders in the process.

Walter Herbst has been helping us develop a glossary of professional terminology for students. Herbst argues that even freshmen should become familiar with the language of the field—terms that mean something specific to designers, their clients, and anyone who runs a shop. Thus this year's course material includes a substantial glossary of terms that students are expected to use with precision. Using this glossary as reference, students will become familiar with blow molding versus extrusion, ethnographic analysis and shadowing, failure modes and latent defects, and Gantt charts versus PERT charts. Herbst maintains that this professional terminology will encourage more professional behavior: for example, when students can distinguish between sketches and drawings, they will more likely appear at the shop with appropriate graphic renditions of their ideas.

Challenges and benefits

This collaboration with professional designers comes with its challenges. Working with outsiders requires extensive meetings as well as significant financial resources to pay them for their services. We spend a great deal of time finding lecturers from the world of design, briefing them on EDC, and helping them develop appropriate content for their lectures.

However, done well, as we believe it is in EDC, this collaboration leads to enormous benefits for all parties. Professional designers gain the following benefits:

- First, as professionals, they have the opportunity to influence how design is taught at a leading engineering school. The engineering students being trained at universities such as Northwestern will eventually be candidates for positions in industry, as well as future clients.

It is to a design company's advantage to influence, through their direct participation, what students are taught about the design process, teamwork, and communication.

- Second, some designers benefit from the opportunity to meet students early in their educational careers and to recruit them for internships and full-time positions. In their roles as clients and faculty, designers get to know these students well and can maintain contact with those that especially interest them.

- Third, in their role as clients, designers benefit directly from the fresh ideas and design approaches offered to them by the student teams and their faculty. IDEO, for example, was very interested in the EDC-developed design for reducing glare in the CAD stations in their Evanston office.

- Finally, a partnership with the academy revitalizes and re-energizes a professional design staff. The professional designers who teach at Northwestern have an opportunity to re-examine their own understanding of design process and commitment to it. They get the chance to follow this tried and true advice: "If you want to understand something yourself, you should teach it to someone else."

Northwestern also reaps many benefits from this collaboration, as the description of EDC suggests. Most importantly, we gain the following:

- *Fresh ideas and approaches to teaching the design process*. The contributions of IDEO and other designers in the last two years have dramatically affected the way we teach design in general, but particularly visual communication as an essential element of design. This was one of our original goals for the course. This contribution can be seen in the increased instruction on sketching and prototyping that students receive as well as in their use of those visualization skills in every phase of their projects.

- *Increased credibility about what we teach.* Freshmen often wonder whether the design process and communication skills they learn in EDC apply to the jobs they will later have as engineers. The guest lecturers and faculty from design offer students convincing evidence that what they learn in EDC will be directly useful to them in their careers.

- *Real world experience across a range of engineering fields.* One goal of EDC, especially in the second quarter, is to offer students projects that expose them to the many different domains of engineering. Our design colleagues have worked with prestigious clients from many areas, and, like our multidisciplinary faculty, are able to show students that design is part of every engineering discipline. This exposure—along with the fact that our projects come from many areas--helps students make more informed decisions when they choose their major field.

The most significant benefit of this collaboration, however, is that by drawing on the practices of

industrial designers and design firms, we have been able to develop a state-of-the-art course in conceptual design adapted to the abilities of freshmen who lack the knowledge to tackle detailed design. This adaptation is a major enhancement to the design curriculum at Northwestern. It allows us to build a foundation and culture of design at the freshman level, teaching skills that faculty in upper-level design courses do not have time to cover. With this foundation in place, students will enter their junior and senior design courses significantly ahead of where their predecessors used to be.

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5. For example, EDC was featured in the New York *Times* education supplement on November 7, 1999, and in the "On Campus" column in *Prism*, November 2000. When the McCormick School went through its ABET review in 1999-2000, EDC was commended for its approach to freshman engineering.

6. In addition to reviews of EDC by faculty at the University of Michigan and the University of Toronto, EDC faculty have been invited to talk about the course at the University of North Carolina-Charlotte (1998) and the Fisher School of Business at Ohio State University (1999). Moreover, EDC was highlighted in the proposal to the National Science Foundation that resulted in the Vanderbilt-Northwestern-Texas-Harvard/MIT (VaNTH) Engineering Research Center for Bioengineering Educational Technologies.

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Biographies

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