Engineering Design and Communication: The Case for Interdisciplinary Collaboration

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Introduction

The engineering faculty at the McCormick School of Northwestern University recently joined forces with the Weinberg College of Arts and Sciences Writing Program to develop a project-based freshman core course: Engineering Design and Communication, or EDC. Over two quarters, students study the design and communication process while working on design projects for real clients. In the first quarter, teams work on a variety of World Wide Web projects for clients at the university. These have included a web-based alternative to Northwestern's course evaluation system, an on-line registration system for intramural sports, and web-based support for NU's new Human Resources software package. In the second quarter, students apply and adapt the process they learned in the first quarter to a new project for another client from either the university, the community, or local industry. For example, students have developed an enhanced pager system for volunteer firemen, a wheelchair design for long-distance recreational use, and a new storage system for a nearby elementary school. The process in both quarters is communication intensive, as students interview clients, work with teammates to develop alternatives, and run focus groups. Deliverables are not only designs, but also well designed, professional looking reports and persuasive oral and written proposals.

We consider EDC a cornerstone course, like many of the innovative design courses that have been developed in the last ten years and have led to the discussions at this conference. [1-4] However, EDC is distinctive in the way that it foregrounds interdisciplinary collaboration, meshing content and pedagogy from two very different cultures. Faculty from engineering and communication collaborate on every aspect of the course: goal-setting, curriculum, lecture content and delivery, project selection, assignments, facility design, team coaching, and evaluation. Weekly lectures, delivered by both an engineering professor and a communications professor, cover both design and communication issues. Similarly, section meetings are run by faculty pairs who share responsibility for supervising project teams, facilitating discussion, and responding to papers. Sections are small, as in a composition class; we run 18-22 sections each quarter with 16 students in each. Ultimately, students receive one joint grade on every project, for design *and* communication. They also receive just one common grade for the course, even though they receive course credit for two.

This integration makes EDC fundamentally different from most engineering courses that emphasize communication. Those writing intensive courses are usually taught by engineering faculty themselves or by members of the communication faculty who collaborate with the engineering faculty but fulfill a subordinate function in the course. For example, English professors or writing center tutors might help students revise or edit final papers. This

kind of collaboration, which we are distinguishing from EDC, became familiar about two decades ago, with the advent of the Writing Across the Curriculum movement, or WAC. We are contending that, in contrast to WAC, it is more advantageous in many ways to offer design and communication in a more fully integrated setting. The interdisciplinary approach to design and communication yields important benefits. It makes freshmen enthusiastic about engineering, exposes them to crucial aspects of design and communication, and most importantly, pushes them toward impressive levels of achievement in both of these fields.

Why teach design and communication as equal partners in a single course?

An interdisciplinary design and communication course offers advantages over an engineering course that is just writing intensive. In a typical writing intensive course, the engineering faculty acknowledge the importance of communication in engineering, may devote several lectures or class sessions to communication instruction, often critique students' writing (and oral presentations), and sometimes collaborate with--or lean on--writing instructors for paper grading. These can be excellent courses; in fact, we've offered successful writing intensive courses at the McCormick School. But in these courses, communication instruction is not an integral part of the intellectual enterprise. Critics of writing intensive courses contend that, regardless of the field, students don't take the writing in WAC courses as seriously as they take the content area.[5] Moreover, in most writing intensive courses or WAC programs, the communication faculty do not share power equally with the design faculty.[6] Typically, communication faculty do not set course goals, write assignments, influence the budget (if there is one), determine final grades, or have much credibility with the students. As a result, critics argue that, while some WAC programs are successful, most fail to qualify as a cornerstone communication experience for students. In general, these courses do not contribute substantially to student learning in writing or show students how the ability to write effectively advances their thinking in the discipline. Ironically, writing intensive courses can reinforce the mistaken ideas about writing that WAC was intended to dispel, for example, that writing is just a set of skills that can be taught separately from intellectual activity or that writing has more to do with spelling and usage than with content.[7]

Mark Turner, a linguist and cognitive scientist from the University of Maryland, and his colleague Francis-Noel Thomas, speak to the fallacy of equating writing with language skills in their recent book, *Clear and Simple as the Truth*:

> Writing proceeds from thinking. To achieve good prose styles, writers must work through intellectual issues, not merely acquire mechanical techniques. Although it is true that an ordinary intellectual activity like writing must lead to skills, and that skills visibly mark the performance, the activity does not come from the skills, nor does it consist of using them. (p. 1)[7]

"Intellectual activities lead to skills," say Turner and Thomas, "but skills do not generate intellectual activities"(p.4).

Turner and Thomas' key point, which helps explain the success of EDC as both a design and a writing course, is that skills are most successfully taught when they are integrated with genuine (rather than academic) activities that build on past learning, create a real need for the new skills, and offer an opportunity to learn them. An interdisciplinary course like EDC improves students' skills in communication and design because it follows this effective

cognitive model: the two disciplines provide a mutually enriching set of genuine activities that allows students to learn the skills that those genuine activities require. Since students need the new skills for EDC projects–skills that overlap the disciplines–the students learn each discipline better together than if they were learning design or communication alone.

For example, when students study writing in a design course, they become better communicators because they are highly motivated to do well. They know they are doing real work; hence, they want to explain their designs precisely and clearly to users, clients, and instructors. Communication faculty can take advantage of this interest to give students substantial guidance throughout the design process, helping them, for example, write more effective interview scripts for potential users, clearer syntheses of their research for progress reports, and more persuasive final proposals for clients. These authentic communication activities, situated in the discipline, give students a concrete way to understand a relatively abstract communication concept–the concept of audience. When students are coached in writing for real clients, students know they are not simply writing for a teacher under fictional or false circumstances. [5,7] Rather, just as students are doing design to fulfill a real need, so too they are writing and presenting to real clients and users. Moreover, the design faculty in an interdisciplinary, project-based course continually emphasize the importance of precise, concise, and professional writing. Their support goes a long way toward validating the communication professors' advice. Working together, both faculties show students that thinking and communication go hand in hand, and that communication in design spans a broader range than they may have realized. EDC emphasizes oral, written, graphical , interpersonal, and even numerical forms of communication.

Just as a design-oriented course provides students with excellent opportunities for becoming more skilled communicators, so does a communication-oriented course provide students with genuine activities that help them become better design engineers. In EDC, students need to communicate their thinking to various audiences throughout the design process: in team and client meetings, user interviews, expert interviews, progress reports, design reviews, and final presentations. As students clarify a description of a design in any of these stages, they more clearly understand their design. This is not surprising to us since clear writing and speaking require clear thinking. However, we were surprised to see the extent to which students are able to improve their designs by having elicited better feedback in client meetings, focus groups, and design reviews.

Design and communication also work well together because they have much in common. Both are iterative, multi-stage processes. Both require creative problem-solving. Both are best taught through coaching and hands-on activities. Both are intellectually reciprocal: just as designs must be communicated clearly to be understood, so must communications be well-designed to achieve their goals. Thus, student learning from this interdisciplinary collaboration is all the more powerful because the concepts and skills in each overlap and those learned in one area apply to the other.

Course overview: EDC in action

EDC owes part of its development to innovative freshman and sophomore design courses from other institutions, such as Clive Dym's at Harvey Mudd College, Woodie Flowers' at MIT, and the D.L. Evans sequence at Arizona State, to name a few. Our students, like students in these other settings, work on open-ended projects tied to real-world problems. However, EDC differs from most other new design courses in three ways: its overarching emphasis on a user-centered approach to the design process, its thoroughgoing integration of

design and communication, and its two-term format, which allows students to acquire a considerable degree of comfort with design process and its communication components.[8]

EDC takes a user-centered approach to design, stressing that the ultimate judge of a device is not a teacher or manager, but the user of the product. We encourage students to learn everything they can about their "customers"—for example, how users are segmented into different groups, the size of the segments, their needs. We also provide students with design tools that will aid them in characteristic design process activities:

--gathering information about users, products, and technologies
--defining complex problems by breaking them down into manageable pieces
--generating alternative designs that address a wide spectrum of user needs
--selecting the best approach to a problem based on well-defined criteria
--managing a long-term team project, using RAM charts, Gantt charts, and team process checks

In addition, we emphasize the role of users as final judges by asking students to get feedback on their design concepts from their target users. Feedback can take the form of interviews or focus groups where a prospective user is shown drawings or models of product concepts. These interviews allow students to determine user responses to various design features; the interviews also ensure that the designers incorporate user needs into design specifications before proceeding to detailed design.

The course spans two quarters so that we can (1) integrate material from both disciplines without sacrificing important material and (2) allow students to work through the design process twice and revise all deliverables two or three times. [9] Communication enters the course in a continuous way as students write problem statements, interview scripts, procedures, meeting minutes, memos to clients, progress reports, and proposals.

The integrated nature of the course is apparent from the first week, when students undertake a one-week hands-on exercise based on the Apollo 13 LiOH canister problem. This requires them to perform a number of overlapping design and communication activities. Working in teams, the students have to design a CO_2 scrubber that the Apollo 13 crew can use on the lunar module. To accomplish this task, students can use only the materials that the astronauts would have had on the spacecraft (which we have simulated and distribute to each team). Students sketch their ideas to share them with their team members, decide on a design, build it, test it, and then write a procedure for the crew. The procedure has to be clear enough, with just words alone, for the crew to be able to duplicate the design.

For the remainder of the first quarter, students design World Wide Web applications that address the needs of clients from the campus community. Web design projects work well because (1) students can learn the basics of Web design quickly, (2) their desk-top computers can help them rapidly develop quite sophisticated prototypes that real users can examine and test, and (3) even modest Web-based designs present teams with interesting challenges, both as engineers and as writers.[10] While working on these projects, students attend a weekly lecture that introduces design process and provides continuity to the course. They also attend two section meetings each week, in which coaching is the primary pedagogy. Additionally, students communicate with

each other and their instructors through *FirstClass* (an electronic conferencing program). They also complete a number of independent software labs. Finally, the quarter culminates in a written proposal and a final presentation to the client.

During the second quarter, students work through the design process again, but they address a variety of design problems that fill a local university, community, or industry need. Again they have real clients. They design such things as playground equipment for a nearby elementary school , a new pager for volunteer fireman, a recreational wheelchair, a new container for the company that sells Bubble Tape©, a novel self-healing composite material, a toy for disabled children. All teams follow a fairly rigid framework defined by the communication assignments associated with phases of design. Once again, students write project plans, progress reports, interview scripts, final proposals or reports, and final presentations. However, teams adapt the process to their project and determine their own timeline for intermediate stages, such as design review. They also have great latitude in choosing how to prototype their design.

By the time they reach the second quarter, students generally feel much more comfortable with design and communication and appreciate the opportunity to apply the process in creative and flexible ways. As one student, who was designing a new door lock for apartments for wheelchair bound residents, explains in a journal entry:

> Because we are not struggling as much with learning the design process . . . [we can] take our projects further than before. . . . Winter quarter served mainly as a time to get comfortable with the design process, while spring quarter has given us an opportunity to really utilize what we've learned in solving a real world problem.

Another student says, "This quarter everything is clearer to me. . . . It is much easier to anticipate the steps of the design process, and therefore our group has improved on time management." Most of the students enjoy the second quarter more, even though they find their projects more demanding.

Second quarter lectures provide additional information about design and a larger view of design in society, covering particular areas of engineering design (such as the role of design in Materials Science), social and professional issues (like ethics) and practical topics such as sketching and prototyping. Again, this focus is well suited to an interdisciplinary approach. Students may be prompted to think about ethics in a lecture given by the former CEO of Bell and Howell, but we also ask them to read about difficult ethical and professional decisions described by noted science writers and journalists such as Freeman Dyson, Henri Petroski, Tracy Kidder, and Jonathan Harr. Students also attend optional engineering tools laboratories that provide instruction needed for the projects; they can receive training in specialized machine tools, advanced research techniques, and specialized computer programs, such as SolidWorks, Thermocalc, and Cambridge Materials Selector. Finally, at the end of the course, students design and write *pdf* or web-based portfolios illustrating their competencies in design.

Conclusion: a positive report

While we have not yet had the opportunity to conduct a study of the long-term effects of EDC–because our freshmen from the first pilot class will just be taking their capstone design courses next year–we do have a growing body of information to support our positive assessment of this interdisciplinary venture. According to engineering faculty at Northwestern, many EDC freshmen produce higher quality reports and presentations than do many of the design teams in the senior capstone courses. Engineering school advisors report positive feedback. And EDC students themselves demonstrate an enhanced appreciation of design and the role of communication in design. As one student commented in a journal,

> I have learned that the design process is not something which is fixed and rigid. It can be approached from many different angles and molded to fit the needs and scope of the project. What is most important is that a thorough job is done with each of the steps and none . . . [is] taken for granted. With this in mind, a successful design can be achieved.

Another says, "[EDC] made me realize that engineers must be able to explain 'how' and 'why' for each and every solution. . . .[E]ngineers do not just solve problems, but they communicate solutions; that is a prominent part of an engineer's work."

The course is also getting positive feedback from new faculty and administrators. Faculty say they enjoy teaching the course. In fact, some say EDC is the most rewarding teaching they've done. One faculty member with industry experience (the principal designer of the Ford Mustang) says, "We're finally teaching design the way it should be taught."[11] Similarly, the engineering deans, alumni, and even the trustees are great supporters of the course. The Undergraduate Dean for Student Affairs claims that EDC is "one of the best things McCormick has going for it."[12] The Associate Dean for the Cooperative Engineering Education Program says she "admire[s] the work of the EDC faculty," who "do a great job . . . [of preparing freshmen] for the expectations to come."[13]

Both theory and our experience suggest that EDC's success is largely attributable to its interdisciplinary core. However, this alone would not be sufficient for success. EDC has required whole-hearted support and commitment from both administration and faculty. At Northwestern, we are fortunate that this support begins at the top, with a provost who is proud of Northwestern's early leadership in interdisciplinary teaching and research.[14] With his support, and the support of the university president and engineering dean, we teach our small EDC sections in an 8000 square foot design studio, equipped with classrooms that have movable worktables and computer stations, a large computer lab, a workshop, office space for faculty, conference rooms for client meetings, etc. EDC also succeeds because a core group of dedicated faculty meet weekly to hash out assignments, plan lectures, write sections of our electronic textbook (or "coursepack"), revise curriculum, set standards for grading, order equipment, train EDC student consultants, and plan workshops for new faculty. This work by the core faculty allows new faculty to enjoy the course and become familiar with its interdisciplinary aspects without being over burdened; new faculty can concentrate on learning unfamiliar content and on becoming accustomed to team-teaching and a coaching pedagogy that is new to many.

We concede that EDC requires a great deal of work, and we admit that interdisciplinary–and especially cross-school–classes are demanding. But based on the feedback we receive and the high quality of the work that EDC freshmen are producing, we argue that an interdisciplinary course like design and communication is a successful model worth emulating.

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