PART ONE

INTRODUCTION

CHAPTER 1: INTRODUCTION

Chapter outline

- Why teach design and communication together?
  - Design and design-thinking: complex processes to solve complex problems
  - Conceptual design vs. detailed design
  - Communication: a central design activity
- EDC course goals
  - Design
  - Teamwork and project management
  - Communication
- A case study: real clients, real projects, real audiences
  - Understanding the background: what the client wants
  - Becoming an expert and identifying the problem
  - Generating alternatives
  - Proposing a solution

> The idea of design—of making something that has not existed before—is central to engineering.
>
> – Henry Petroski, *To Engineer is Human* (1985, p. xi)

This textbook for Engineering Design and Communication (EDC) will introduce you to what most people consider the heart of engineering: complex problem solving that leads to new products and solutions. The text has been written just for you—McCormick freshmen in the introductory course in design and communication. EDC teaches you design while you actually do design. From the beginning, you'll be working on real projects—involving real people who need your products and audiences who are not simply your instructors. The textbook will introduce you to the design and communication process you’ll need for doing that work well.

The best way to use the textbook is to read the required sections listed in the syllabus, and then to review the specific sections that are relevant to your projects when you need them.

1.1 WHY TEACH DESIGN AND COMMUNICATION TOGETHER?

1.1.1 Design and design-thinking: complex processes to solve complex problems

Societies are often known by their achievements in design, such as their pyramids, roads, or computers. It is the designer or engineer who synthesizes these new forms, who develops the ideas, goals, and requirements for the production of bridges, automobiles, and electric guitars. Henry Petroski, professor of Civil Engineering at Duke University and author of *Invention by Design: How Engineers Get from Thought to Thing* (1996), says that design and development distinguish engineering from science. Scientists primarily want to understand "the world as it is," whereas engineers "wrestle" with ways to erect great monuments, or design defenses against enemies, or move people and goods across rough terrain (p. 2). Engineering, Petroski explains, is the "art of rearranging the materials and forces of nature" (p. 1).

Petroski's formulation suggests that design is not so much a "thing" as it is a complex activity, a process. When engineers talk about "the design process," they're actually using a shorthand term to describe one of several systematic approaches to problem solving with fairly predictable results. In its most basic form, design process starts with brainstorming and proceeds logically all the way to fabrication. But it's also a creative process that varies from person to person. There is no one correct way to describe the design process, no one right way to do design, no single set of steps or theory to follow. Petroski (1996) explains that design process—what it takes to get a high-tech computer from an "inventor's brainstorm to our desk"—is rarely straightforward: "It can entail decades of painstakingly slow research and development, followed by weeks of frenzied activity" (p. 1). Nonetheless, most descriptions of design process include interrelated steps like the following, the steps we use in EDC and in this textbook:

- Gathering information in order to understand the problem
- Defining the problem by identifying users and their needs
- Generating design alternatives
- Making mockups (sketches or simple models) of alternatives
- Testing the alternatives
- Deciding on a design direction
- Building more mockups
- Presenting a design for peer review
- Revising the design and building more mockups for testing
- Presenting supervisors and clients with deliverables (a final report, a poster or oral presentation, and a prototype)

Each step includes sub-steps or techniques and tools that you will use to develop your designs. Like the main steps, these aren't always done in the same order. That's because the design process is essentially iterative rather than sequential. Design engineers don't just start at the beginning of a list of steps and then march through each step until they reach the final design stage. Rather, as Figure 1.1 illustrates, they continually re-visit the various stages as they gain additional knowledge. The list above provides a hint of this in the iteration of steps that involve building mockups, testing, and revising the design.

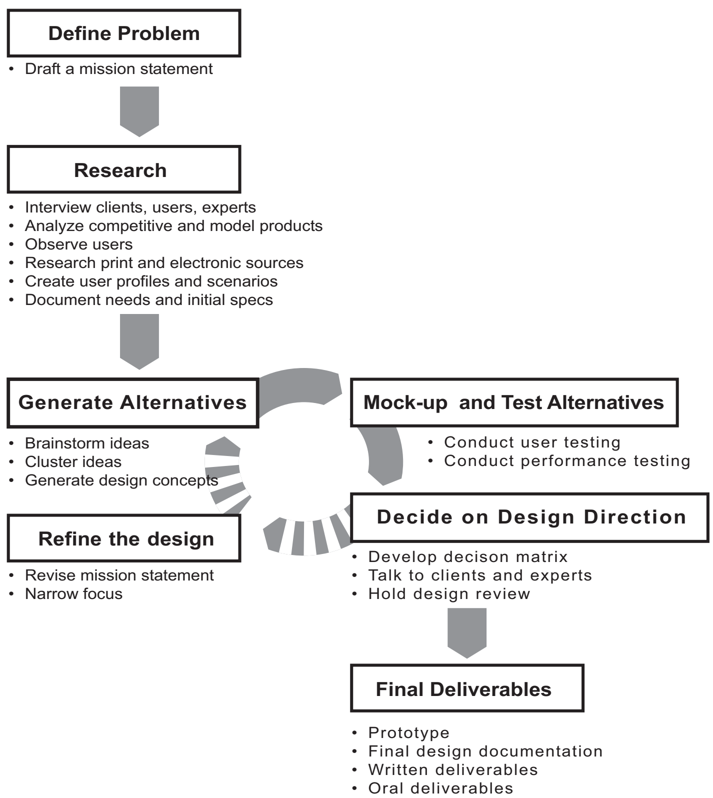

Figure 1.1: Recursive design process

In your spring quarter projects, for example, your client may tell you that she would like to develop a new type of automobile seat belt that can be fastened easily by people with arthritis. You will do research: interview seat belt experts, analyze competitive and model products, and observe potential users. Based on this information, you will mock up some alternative designs that you think will accomplish your client's and users' needs. However, once you test these mockups on users, you may find that users actually want something quite different from what the client first described to you and from what they were originally able to imagine. So you go back to your client with this information, and may end up re-defining the problem and designing a radically different product, such as a handheld device that helps people manipulate existing buckles. With this new idea in mind, you go back to users and experts with new mockups. The design process is just as much a loop as it is a line:

you continually move forward—closer to your goal—but not without re-tracing many of your steps.

1.1.2 Conceptual design vs. detailed design

Design process can be divided into two large phases: conceptual and detailed. Conceptual design is the systematic process of developing a general solution to a problem but not performing all the calculations and the evaluations of components, materials, and manufacturing processes necessary for implementation of the design. Detailed design, by contrast, is the process of performing necessary calculations and evaluating components, materials, and manufacturing processes in order to see a design through to implementation.

Beginning engineering students aren't expected to take a project all the way through to detailed design. To do that, you'll need more advanced knowledge of math, physics, and computers, and you will need to acquire expertise in a specific engineering discipline, such as chemical engineering or materials science. EDC stresses conceptual design. Later in your engineering career, you will take your design ideas through implementation.

Well before that time, however, you can familiarize yourself with design process and develop ideas for solving problems. That way, by the time you work on a capstone project as a senior or take a job in industry, you will already know how to define problems, generate alternatives, interview clients, write reports, and give presentations. You will also understand something about the ethical issues that are prominent in design and the role that design plays in society.

1.1.3 Communication: a central design activity

It makes sense to study communication while you study design because communication is an integral part of design: the design process requires communication at every step of the way. In their book, *The Engineering Design Process* (1996), Atila Ertas and Jesse C. Jones state:

> Engineers in industry often comment on the large amount of their time that is committed to writing and other forms of communication. Most business and industry communications are verbal, in the form of face-to-face discussions, meetings, and telephone conversations. Important communications are transmitted in writing so that the meaning can be precisely stated and a record can be established for future reference (p. 470).

As a design engineer, you'll have to communicate with experts, clients, and team members. You'll be communicating not only when you write reports and give oral presentations, but also when you sketch ideas, build mockups, and provide graphs and equations. You'll need strong interpersonal skills for working successfully in client and team meetings. You'll need to write minutes, memos, emails, and project plans just to organize your work.

But the connections between design and communication do not end there. A real design, as opposed to a fuzzy idea, is something you can articulate and explain to others. Therefore, as you become a skilled communicator, you will become a better design engineer.

Design and communication even share similar thinking processes. A writer, for example, follows steps that resemble the stages of design:

Table 1.1: Comparing design and writing

Design	Writing
Gathering information	Collecting the information you need to communicate
Defining the problem	Identifying your main point, audience, and purpose
Generating alternatives	Outlining different ways to organize the information
Making mockups	Writing a rough draft
Testing the mockups	Getting feedback from peers and instructors
Building more mockups	Revising the draft
Presenting the final deliverables	Delivering the final version of the report, proposal, and/or oral presentation

Like the design process, the writing process is iterative; that's why writers call their different drafts "revisions" ("re-vise" means "to see again"). You can write a clearer final report once you ask a reader to review it. You can figure out if a set of instructions is clear by watching people try to follow it.

Good communication, then, isn't just a matter of correct grammar and punctuation—or of eloquence and style. Rather, it's a form of problem solving, like design. This is especially true of long, complicated documents that require clear organization of complex material along with visual cues, such as headings, to show readers where to find information.

Engineering students often worry about writing and presenting; you may feel more comfortable with numbers and sketches than with sentences and paragraphs or with presentation skills. If so, then EDC should put you at ease; this course will show you that good problem solvers have the logical ability to be good communicators, too. In both design and communication, you'll use your analytical skills to succeed.

1.2 EDC COURSE GOALS

Over the years, there have been EDC students who have approached the course as if there were nothing new to learn; they say that design and communication are simply common sense, that all a designer needs is intelligence and ingenuity.

But that is not true. If it were true, then there would not be so much bad design in the world. If it were true, then the course would not have the support of top engineering and design firms who say that EDC teaches what students need to learn. If it were true, then employers would not value the abilities of our top design students so highly. And finally, if it were true, then we would not hear back from graduates who say what they learned in EDC was immediately applicable in their jobs—and they are grateful to have learned it.

The fact is that design and communication, while not overly difficult, are also not intuitive. There is a lot to learn in EDC. Not only will the course give you an opportunity to apply what you are learning in Engineering Analysis (for some projects), but it will also teach you skills and processes that lead to valued results.

The three lists below detail the learning goals of EDC in its three major areas: design, teamwork (including project management), and communication. All of the topics are discussed in this textbook. Look over these lists at the beginning of the course to get an idea of where you will be going in EDC. Then at the end of each quarter, review them. You may be surprised at how far you have come.

1.2.1 Design goals

In EDC, you will learn how to:

- define engineering problems clearly and precisely with the client's and users' needs in mind
- gather information about design problems and possible solutions from a variety of sources: clients, users, experts, print sources, online sources, etc.
- generate alternative solutions to design problems
- build and test mockups that embody your alternative solutions
- improve designs based on information solicited from clients, users, and your fellow designers

- analyze designs to understand the risks and benefits they present to users and society
- embody your final design concepts in a prototype and detailed drawings

1.2.2 Teamwork and project management goals

In EDC, you will learn how to:

- manage the team formation process
- work successfully as a team by establishing team goals and standards, allocating responsibilities fairly, benefiting from team members' strengths, and using effective interpersonal communication
- monitor team performance and provide feedback to teammates
- manage team conflicts
- use project management tools, such as RAM charts and Gantt charts, to track responsibilities and develop a project timeline
- hand off the results of your project to your client or to a future design team

1.2.3 Communication goals

In EDC, you will learn how to:

- use writing and speaking to help develop and communicate design concepts
- use the writing process—gathering information, planning, drafting, and revising—to produce clear, concise, and persuasive documents
- write documents commonly used in engineering such as final reports, progress reports, technical posters, instructions, emails and PowerPoint slides
- write to both technical and non-technical audiences
- use sketching throughout the design process to communicate ideas
- make effective oral presentations, using PowerPoint, to communicate a design
- create effective posters and present them clearly and persuasively in poster display sessions
- document and archive all work done on a project
- collaborate with others to produce documents and presentations
- conduct well-organized, efficient, and productive meetings

Throughout the course, you will consider all three areas—design, teamwork, and communication—in relationship to a design engineer's ethical obligation to make safety, integrity, and social responsibility a fundamental part of his or her work.

1.3 A CASE STUDY: REAL CLIENTS, REAL PROJECTS, REAL AUDIENCES

The case of the Filing System design team (Andrew Cibor, Tiffany Leung, Ivan Santana, and Chad Wastell) illustrates how the design process you will learn in EDC leads to a successful design. As you'll see, team communication, as well as communication with the client, is integral to the design process, and one key to its success.

1.3.1 Understanding the background: what the client wants

The idea for this project began when Ms. Ann Stuart, Program Coordinator for Industrial Engineering and Management Science in Northwestern University's McCormick School of Engineering, came to EDC with the request that students design something that would help her to organize the large number of papers, folders, brochures, and pamphlets she kept on her desk. She was well aware that office supply companies sell numerous filing cabinets, trays, and other equipment for this purpose. However, she believed that she would be better served by a revolving under-the-desk file cabinet tailored to her specific needs. She was not looking for a product that she could market but rather one that she could use to help her work more efficiently.

1.3.2 Becoming an expert and identifying the problem

Ms. Stuart's description of the problem was helpful to the Filing System team, but they wanted to understand the problem better before agreeing that her description was correct and that her proposed idea—a revolving file cabinet to be stored under her desk—would be the best solution. They needed to see for themselves exactly how Ms. Stuart organized the material on her desk and what was ineffective about her methods. Therefore, they made an appointment to meet in her office to learn about the problem firsthand. To prepare for this meeting, they wrote a detailed script of all the questions they wanted to ask. At the meeting, they not only asked her about her current methods of organizing her desk, her problems with those methods, and her under-the-desk solution, but they took photographs that they could analyze later (see Figure 1.2).

The team also arranged to have a member return later in the week to spend an hour observing her as she went about her daily routine. This observation session proved invaluable in providing the team with an understanding of the problem. Of particular importance was their observation that Ms. Stuart was visually oriented: she had to be able to see the needed materials on her desk clearly. If a file folder was hidden by something else, she tended to forget about it. This observation suggested that an under-the-desk solution would not be appropriate because everything in that file cabinet would be hidden from view.

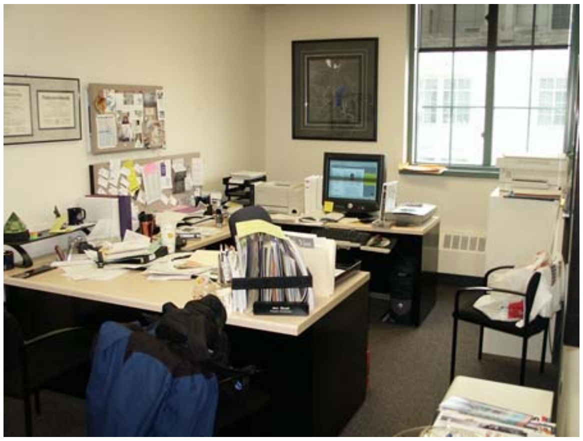

Figure 1.2: Initial view of client's desk

To further understand Ms. Stuart's problem, the team interviewed and observed other Northwestern program coordinators who were successful in organizing their desk space. The students learned that these people's success lay as much in organizational habits they had developed over the years as in their specific desk equipment. For a short time, then, the team thought that their problem was to change Ms. Stuart's habits by writing a set of instructions for organizing her desk space. However, further observations and interviews with Ms. Stuart persuaded them that her habits were so ingrained that this was an unrealistic goal. So they defined their problem as designing a physical structure that would:

- significantly improve Ms. Stuart's organization of her supplies, loose papers, and folders/projects
- be easily used while she remained in her chair
- fit her specifications in both size and appearance

The team detailed the problem and user requirements in a written document called a "project definition."

1.3.3 Generating alternatives: What ideas might lead to solutions?

Once the team had defined the problem, they could begin to develop alternatives for solving it. They brainstormed a large number of design ideas ranging from labeled trays, sliding shelves, and color-coding to wild ideas like a scrolling marquee of reminders. They also looked online at office supply company websites for ideas. Using all of these ideas, as well as the list of key design requirements they had compiled, the team generated three alternatives, which they quickly mocked up using foamcore. The team's sketches of two of those alternatives (which they called "stackable sloped tray" and "lazy susan") are presented below in Figures 1.3 and 1.4:

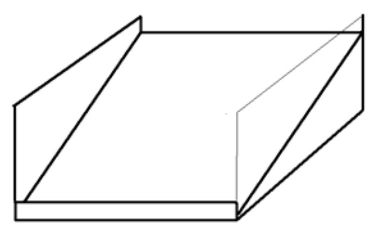

Figure 1.3: Alternative one for filing system project—stackable sloped tray

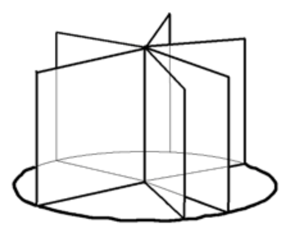

Figure 1.4: Alternative two for filing system project—lazy susan

These alternatives were not intended to be final designs, but rather to be used to solicit additional information about possible features for the design. For example, which orientation of her papers would Ms. Stuart find easier to work with: horizontal (in the sloped tray) or vertical (in the lazy susan)?

The students asked Ms. Stuart to use each mockup for a day, after giving her instructions on how they thought it might be used. In each case, they returned the next day and interviewed her—using an interview script they had written for this purpose—on what she did and did not like about each mockup.

With her responses in mind, they developed two new alternatives that had features of the previous mockups but were in general quite different. One—now called "the filer"—incorporated the lazy susan idea but used a different configuration of dividers. The other mockup—now called “the big one”—used slanting shelves but no longer in stacked trays (because Ms. Stuart found it difficult to find papers in the lower trays). See Figures 1.5 and 1.6:

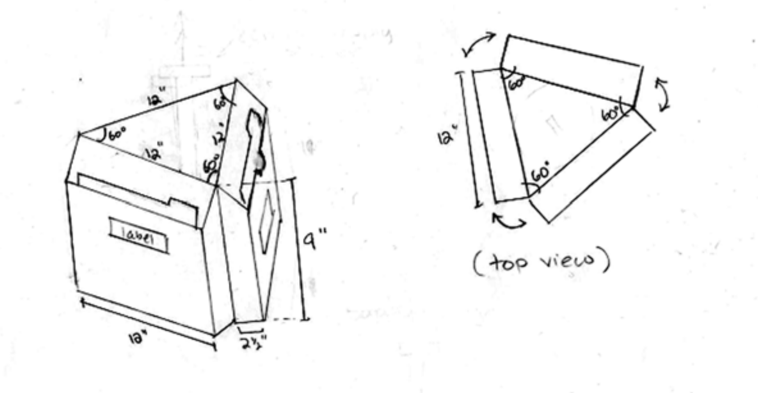

Figure 1.5: New alternative one for filing system project—the filer

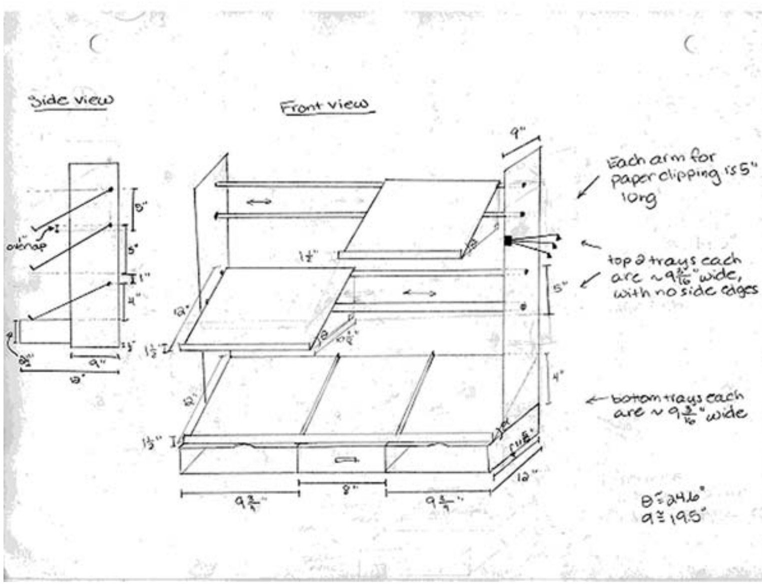

Figure 1.6: New alternative two for filing system project—the big one

These new mockups were subjected to constructive criticism by instructors and fellow students in a formal design review.

1.3.4 Proposing a solution

Based on the feedback they received in the design review, the team decided to recommend both design concepts to Ms. Stuart. They fine-tuned both designs, drew up dimensioned drawings (see Figure 1.7 for a dimensioned drawing for one design, now called “the tri-level organizer”), and presented their solution to Ms. Stuart in an oral presentation and written final report. They also gave her the more complete of their two mockups—the “Rotational Filer”—which she was delighted with and eager to use.

As you can see, the Filing System Design Team followed the design process described earlier in this introductory chapter, but performed many of the steps simultaneously or recursively. Communication was a key part of the process throughout: they communicated with each other, their client, their instructors, and others on a regular basis, and they used all forms of communication—written, spoken, graphical, numerical, and interpersonal.

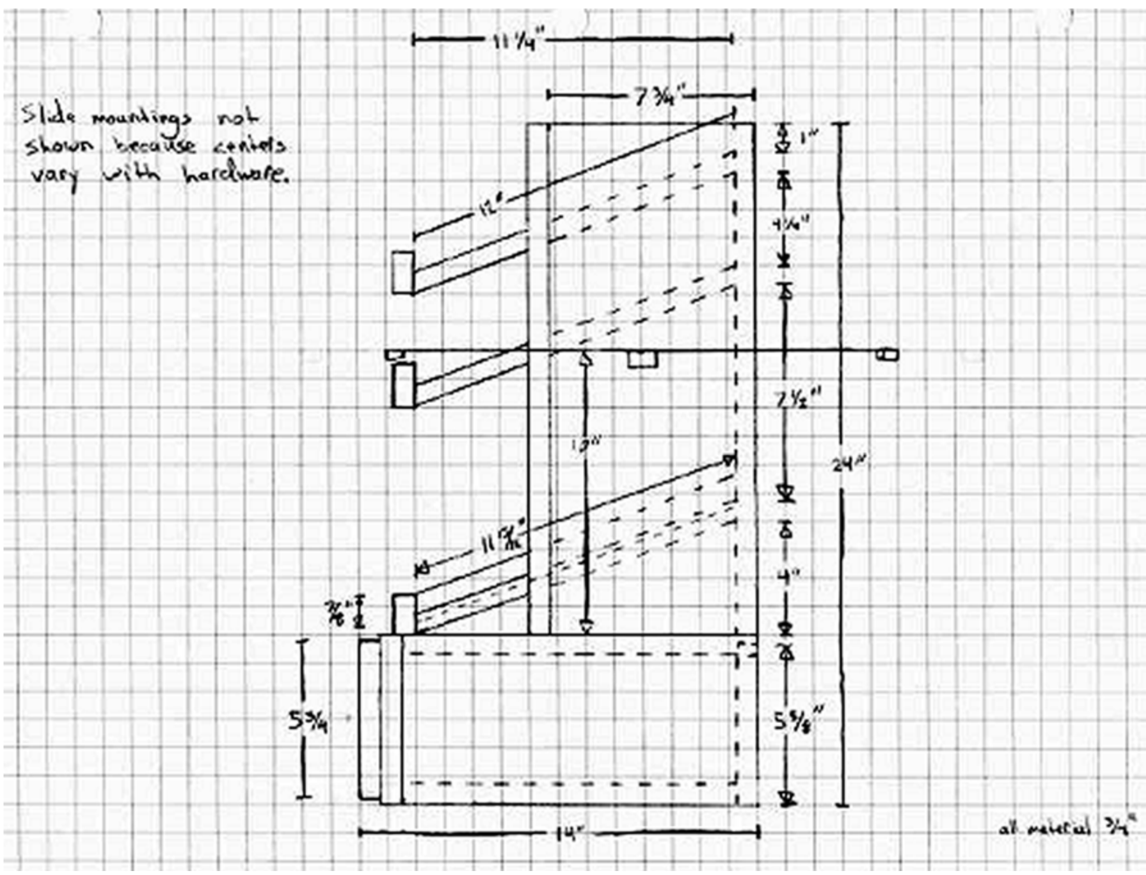

Figure 1.7: Final drawing for the tri-level organizer

1.4 REFERENCES

Cibor, A., Leung, T., Santana, I. & Wastell, C. (2002). *Filing system proposal*. Engineering Design and Communication, Northwestern University.

Ertas, A. and Jones, J. (1996). *The engineering design process*, 2nd ed. New York: John Wiley and Sons.

Petroski, H. (1985). *To engineer is human: the role of failure in successful design*. New York: Vintage Books.

Petroski, H. (1996). *Invention by design: how engineers get from thought to thing*. Cambridge, MA: Harvard University Press.