DESIGN

creation of artifacts in society

Karl T. Ulrich

Contents

Chapter draft of September 2007.

ONE

Introduction to Design

Here are some of the human activities characterized as *design*:

Architectural design
Automotive design
Business design
Ceramic and glass design
Color design
Communication design
Engineering design
Environmental design
Experience design
Fashion design
Floral design
Furniture design
Game design
Garden design
Graphic design
Industrial design
Information design
Instructional design
Interaction design
Interior design
Landscape design
Lighting design
Machine design
Mechanical design
News design
Packaging design
Product design
Production design
Service design
Software design
Sound design
System design
Theatrical design
Type design
Urban design
User experience design
User interface design
Web design

The word *design* presents definitional challenges. Designers tend to view their own particular sphere of activity as the universe of the human activity of designing. For example, a group of faculty at my university have ambitiously declared themselves the *School of Design.* The school does comprise two clearly recognizable design activities—architecture and urban design--but curiously also fine arts and historic preservation. At the same time, the trade journal *Design News*, with a subscription base of 170,000, focuses quite narrowly on engineering design. I can't think of another human endeavor with such confusing intellectual jurisdictions.

Part of the problem is the English language. What we call *design* in English goes by several different words in other languages. For example, in German the words *konstruktion*, *bauart*, *entwurf*, *planung*, and *design* are all

used to refer to activities we call design in English. (See the Appendix to this chapter for an overview of the etymology of the word and synonyms in other languages.)

Fortunately, at the level at which I treat design in this book, the activity of design is fundamentally similar across a wide variety of domains.

Design is conceiving and giving form to artifacts that solve problems[1].

I use *artifact* in the broadest sense to describe any product of intentional creation, including physical goods, services, software, graphics, buildings, landscapes, and processes. These artifacts can be categorized into *domains*, within which specialization of design methods can be useful.

Exhibits CODE through FFA are some examples of artifacts in different domains, all designed[2]. Each artifact was conceived and given form to solve a problem. The *form* for artifacts need not be geometric. For example, the computer program in Exhibit CODE takes for form of a nested list of symbols. The *problem* need not be a pressing societal need, but rather any perceived gap in a user's experience. For example, the Insalata Caprese is a wonderful artifact, but hardly addresses a *problem* in the deepest sense of the word.

```
(define (smallest-divisor n)
  (find-divisor n 2))
(define (find-divisor n test-divisor)
  (cond ((> (square test-divisor) n) n)
        ((divides? test-divisor n) test-divisor)
        (else (find-divisor n (+ test-divisor 1)))))
(define (divides? a b)
  (= (remainder b a) 0))
```

Exhibit CODE
A computer program to find the smallest divisor of an integer N, written in *Scheme*, a dialect of the programming language LISP (Abelson and Sussman 1996).

[1] This definition draws on those proposed by at least two others. Edgar Kaufmann, Jr. (curator of the industrial design department at MOMA, 1946-1948) wrote "design is conceiving and giving form to objects used in everyday life." Klaus Krippendorf and Reinhart Butter (1984) wrote "Design is the conscious creation of forms to serve human needs."

[2] See the three-volume set Phaidon Design Classics for 999 "industrially manufactured objects of aesthetic value and timeless quality." While a more limited definition of design than I adopt in this book, the Phaidon Classics are nevertheless a fascinating collection of artifacts.

Exhibit CAPRESE
Insalata Caprese, allegedly originally from the island of Capri in the Campania region of Italy.

Exhibit RODS
Connecting rods for an automotive engine. Source: LN Engineering.

Exhibit LOGO
The logo for Xootr brand scooters. Source: Lunar Design.

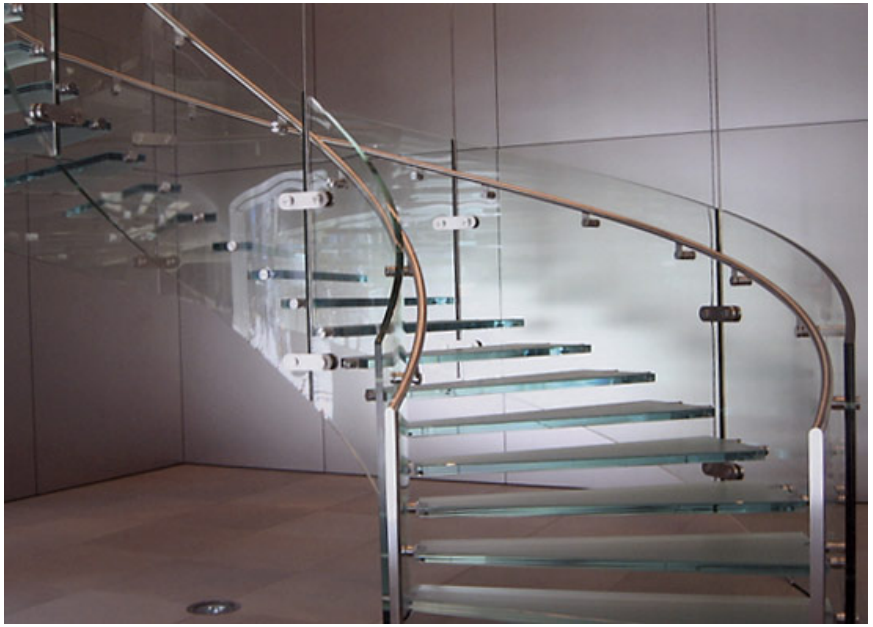

Exhibit STAIR
A glass staircase for the Apple Store in Osaka, Japan. Source: Bohlin Cywinski Jackson (or Koji Okumura?).

Exhibit CAM
The Sony Cyber-Shot digital camera. Source: Sony Corporation.

Exhibit JET
The Eclipse jet. Source: Eclipse Aviation.

Exhibit FFA
Fisher Fine Arts library at the University of Pennsylvania. Designed by Frank Furness and completed in 1890. Source: wikipedia.

Unifying Framework

From code to cameras and logos to libraries, design domains are highly diverse and the tools and methods used by designers in these domains can be highly specialized. However, the activity of design across all domains can be usefully unified by a single framework.

I adopt an information processing view of design, largely consistent with that articulated by Herbert Simon in the 1960s (1996). From this perspective, design is part of a human problem solving activity beginning with a perception of a *gap* in a user experience, leading to a *plan* for a new artifact, and resulting in the *production* of that artifact (Exhibit MODEL)[3]. This problem solving process includes both design and production of the artifact. Design transforms a gap into a plan. Production transforms a plan into an artifact.

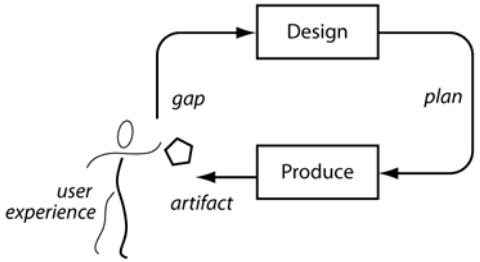

Exhibit MODEL
Design and production are the two activities that deliver artifacts to address gaps in the user experience.

Exhibit 4STEPS further decomposes the design portion of this process into four steps. This is a codification of a process that may be implicit for many designers, yet these elements can be discerned in some form in most design efforts:

- **Sense gap.** Design begins with a perception of a gap in the user experience. Without a gap, there is no motive for design. The gap may be perceived by users themselves or by observers.
- **Define problem.** In effect, problem definition is the creation on the part of the designer of an explanation of why the user experiences a gap. This diagnosis can be thought of as an identification of user needs that are not being met in the current state and/or the recognition of criteria for a high-quality solution. Problem definition is implicit in many design efforts, particularly when users are designers, but is generally an explicit part of professional design efforts, expressed in the form of a design brief, customer needs list, or other document.
- **Explore alternatives.** Given a problem, designers almost always explore for alternatives. (This step is sometimes called *search*.) I devote the entire next chapter to exploration, as it is a hallmark of design.
- **Select plan.** Exploration typically exposes more than one solution alternative and so design requires some sort of evaluation and selection from among alternatives. Some designers consider many alternatives simultaneously when selecting a plan. Others articulate, evaluate, and refine plans iteratively and select the first plan that is good enough.

[3] Terwiesch (2007) provides a comprehensive discussion of product development as problem solving. Product development is a specific economic activity that includes design tasks.

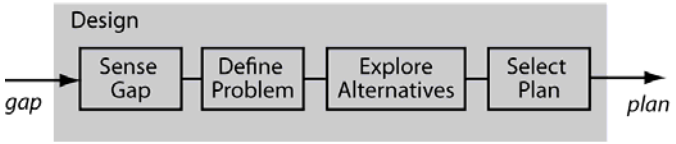

Exhibit 4STEPS
Design can be thought of as four information processing steps.

Note that in the model I present here, design proceeds from experience to diagnosis to plan to artifact. In modern enterprises, the order is sometimes reversed. The designer sometimes begins with a plan and searches for needs that the design might meet. This approach is typical of endeavors for which effective exploration methods are lacking, e.g., pharmaceuticals and basic materials. The reverse sequence of design steps is sometimes called *technology push* because it begins with a solution rather than with a gap[4].

[4] See Terwiesch and Ulrich (2008) for a more comprehensive treatment of various modes of innovation in industrial practice.

The design process is typically executed multiple times, as the first artifact produced rarely results in a complete closing of the gap in the user experience. This iteration may occur across different time scales, ranging from high-frequency iterations by a single individual perhaps over minutes or hours to low-frequency iterations over multiple generations of artifacts within an entire society. For example, Rybczynski (2000) provides a detailed chronicle of the evolution of the screw and screwdriver as many iterations of problem solving over hundreds of years.

What is Good Design?

Design is difficult in that it absorbs substantial cognitive effort, typically requires multiple iterations, and rarely results in an optimal artifact, even in situations for which a formal notion of optimality is possible. The few design domains that have been described by formal mathematical languages are, in the nomenclature of computational complexity, *NP-complete* search problems, meaning that the theoretically optimal solution can not be reliably found[5]. Most design domains have not even been formalized, making the inherent complexity even greater and the prospect of optimality even more distant. However, users can generally still evaluate the quality of the outcome of the design process, and different artifacts designed to address the same gap can certainly exhibit markedly different levels of quality.

Design quality is derived from how well the artifact satisfies user needs, and thereby closes the perceptual gap in the user experience. The quality of an artifact is linked to at least these characteristics of the design process:

- How well did the designer diagnose the gap in the user experience? Is the problem as understood by the designer consistent with the causes of the gap experienced by the user? In simple terms, did the designer understand the problem?
- Has the scope for exploration been defined in a way that the space of possibilities includes high-quality solutions? In the nomenclature of cognitive psychology, has the design problem been *framed* in a way that allows for high-quality solutions to be found?

[5] *NP* means that the time required for an agent to find a solution increases with the size of the problem according to a relationship that is *not polynomial* (e.g., exponential, factorial, etc.). In other words, the problem "explodes" in magnitude in a way that finding a truly optimal solution is impossible in a reasonable amount of time, even with very fast computing.

- Did the designer succeed in finding high-quality designs within the solution space that has been defined? Often this result depends on both the skill and knowledge of the designer and on the ease and accuracy with which the designer can forecast the quality of a design without actually having to produce it.

Of course, although not an attribute of the design process per se, the fidelity of production of the plan is also a determinant of user satisfaction.

In sum, did the designer understand the problem, frame it in a way that exploration could potentially find a good solution, find such a solution within the solution space, and deliver an artifact consistent with the design.

Another way of thinking about design quality is to identify *defects* that can arise in the design process. For each element of the process, there is at least one potential defect: The designer may fail to accurately diagnose the gap in the user experience. The designer may frame the exploration problem in a way that excludes many high quality designs. The designer may only be able to explore a limited portion of the solution space, finding only a few relatively lower-quality solutions. The artifact produced may not be an accurate embodiment of the plan.

Design is Everything?

The marketing consultant Regis McKenna wrote a famous article in *Harvard Business Review* entitled "Marketing is Everything." I know several designers whose blood boiled in response to this title. A common refrain among designers is that indeed *design* is everything (and certainly including marketing). I'm sympathetic to this view, having observed a lot of dysfunctional managerial and political processes that would be substantially improved by the application of the basic design process. (How often have you participated in a group effort for which no one had clearly articulated the problem, explored alternatives, nor carefully selected a plan from the alternatives?)

However, there is a lot of human problem solving that is not really design. The interactive, incremental, on-going development and refinement of abilities that occurs between a coach and a performer doesn't quite strike me as design. Trading of financial instruments on Wall Street does not seem to me to involve much of what I think of as design. Construction of a building to faithfully execute a plan, even with the application of remarkable skill and craft, is hardly design.

The final chapter of this book takes on directly the question of how design relates to human problem solving more generally. For now, let me just state that I believe that much of human problem solving would benefit from *more* design process not less, but that I don't believe that so-called "design thinking" addresses all challenges we face as individuals, managers, politicians, organizations, and institutions.

This Book

The central theme of this book is that a unifying framework informs the human activity of design across all domains. With few exceptions, each idea in this book applies to graphics, environments, products, software, services, machines, and buildings. My dream is that an understanding of the design process be integral to the primary, secondary, and post-secondary education of all individuals in modern society. This book is an attempt to lay out some of the ideas that would form that education.

Earlier I alluded to the Nobel-Prize-winning economist Herbert Simon and his information processing view of design. Simon was brilliant and his book *Sciences of the Artificial* has some beautiful ideas in it. In some ways it was the first serious intellectual treatment of design with a capital D. But, despite all his merits, Simon didn't really know much about the creation of real artifacts. With this book I aim to marry serious concepts to the way real artifacts are created in society. I also hope to cover some of the big ideas that have been developed in the fifty years since Simon wrote about design.

This is a book about ideas. It is not a handbook for *doing* design. I am writing for three audiences. First, I am writing for designers with an interest in ideas about the design process. This isn't a huge population. I have spent my whole professional life working with the nuts and bolts of design and I know that few designers have much patience for ideas like those in this book. One of the reasons they became designers was to *do* design, not *think about* design. Second, I am writing for those who do not think of themselves as professional designers, but who have an intellectual interest in design. This is a bigger group than the first, but still not exactly the audience for *The DaVinci Code*. Third, this book is intended for university students and their instructors. There are very few design courses that are part of what might be considered general education in universities. This is unfortunate. I'd like to teach such a course, but as I look at my own university's core curriculum,

design does not fit neatly into one of the general education requirements[6]. However, there are a lot of courses on design or related to design in which one or more of the chapters in this book will be useful. For example, I use the chapters on aesthetics and variety in my *product design* course, which is largely a course delivering professional skills to those who want to design products.

This book assumes no specific disciplinary training. Economic principles are typically defined. Any engineering concepts used are typically explained. The mathematics, even though scarce, is basic. However, there is certainly an underlying tone to the book that arises from my own personal training and worldview. I'm a hyper-rational, structured thinker with training in engineering, computer science, and business. I know my approach will drive some readers nuts.

The book has six more chapters:

2. Exploration
3. Users, Experts, and Institutions in Design
4. The Architecture of Artifacts
5. Aesthetics in Design
6. Variety
7. Problem Solving and Design

These are not all the topics one could address within the theme of this book. For example, I don't have much to say about organizations within which most real design gets done. I may write on this and other topics in future editions. My bias is to get the basic ideas out and to refine, improve, and augment them, rather than wait until I can deliver a more comprehensive treatment of the subject.

References

Harold Abelson and Gerald Jay Sussman. 1996. *Structure and Interpretation of Computer Programs*. 2nd Edition. MIT Press. Cambridge, MA.

[6] In the undergraduate College at the University of Pennsylvania, the core curriculum comprises *communication*, *analysis*, and *perspectives* plus seven "sectors" (*society*, *history*, *arts & letters*, *humanities & social science*, *the living world*, *physical science*, and *natural science & mathematics*). Where would you put design? Is design (or perhaps human problem solving more generally) less important than the required topics under these categories?

Klaus Krippendorff and Reinhart Butter. 1984. Product semantics: exploring the symbolic qualities of form. *Innovation*. Vol. 3. No. 2.

John Maeda. 2006. *The Laws of Simplicity*. MIT Press. Cambridge, MA.

John Maeda. 2007. Two Words on Design. *Technology Review*. May/June. p. 32.

Regin McKenna. 1991. Marketing Is Everything. *Harvard Business Review*.

The Oxford English Dictionary. 2nd ed. 1989. Oxford University Press.

Phaidon Design Classics. 2006. Volumes 1-3. Phaidon Press. London.

Witold Rybczynski. 2000. *One Good Turn: A Natural History of the Screwdriver and the Screw*. Scribner. New York.

Herbert A. Simon. 1996. *The Sciences of the Artificial*. Third Edition. MIT Press. Cambridge, MA.

Christian Terwiesch. 2007. Product Development as a Problem-solving Process. in S. Shane (editor). *Blackwell Handbook on Technology and Innovation Management*. forthcoming.

Christian Terwiesch and Karl Ulrich. 2008. *Mastering Innovation: Managing the Value Creation Process*. Forthcoming.

Appendix: The Word *Design*

The word *design* comes to English via French from the Latin root *signum* and means literally to mark out. It was first used in English in the sense I use it in this book in the 17th Century (OED 1989). By now, the word has assumed many meanings and covers a lot of territory in the English language. Exhibit WORD shows the words in several other languages that are used similarly to the way *design* is used in English. German has perhaps the most different terms for more precisely characterizing the different notions of design. Many of these words come from Latin roots, which are probably recognizable to most readers. Interestingly, the English word design is popular in other languages and has been adopted either exactly or phonetically (e.g., *dezain* in Japanese). In some of these languages, a word similar to *design* derived more directly from Latin and/or French has a different meaning. For example, in Italian, *designare* has the very narrow meaning to *draw*, and either the English word "design" or the word *progettazione* (verb *progettare*) are used to

refer to the activity of design, and in French, the word *désigner* means to designate, not to design, and either "design," *dessein* or *conception* are used.

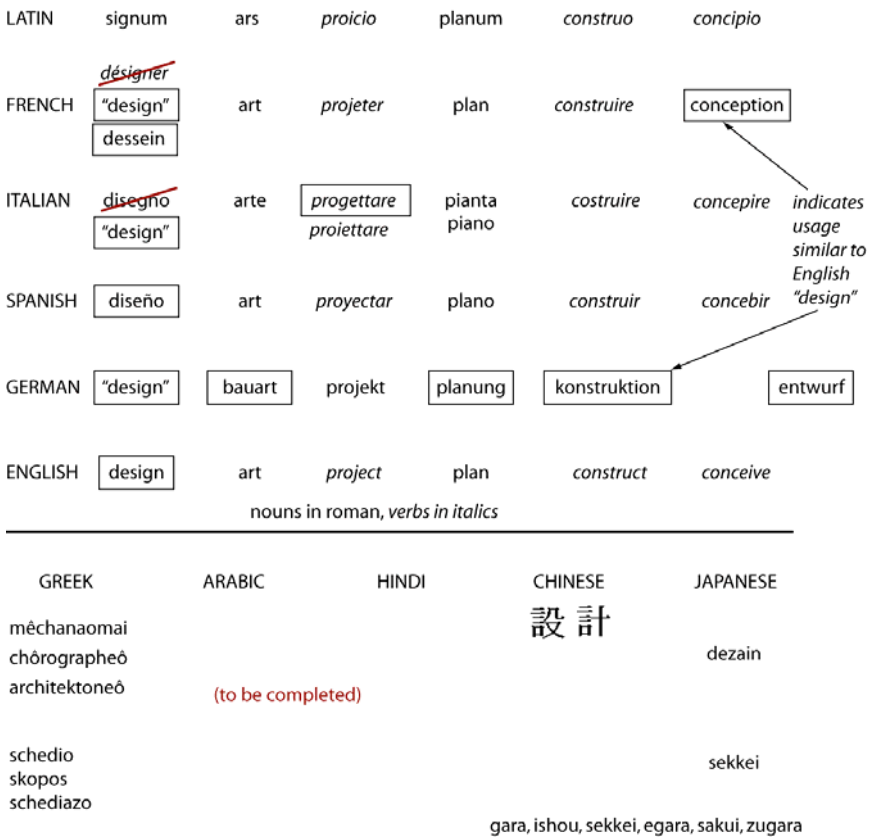

Exhibit WORD
Words in several other languages used in a way similar to the English word design. The most similar terms are outlined with boxes.