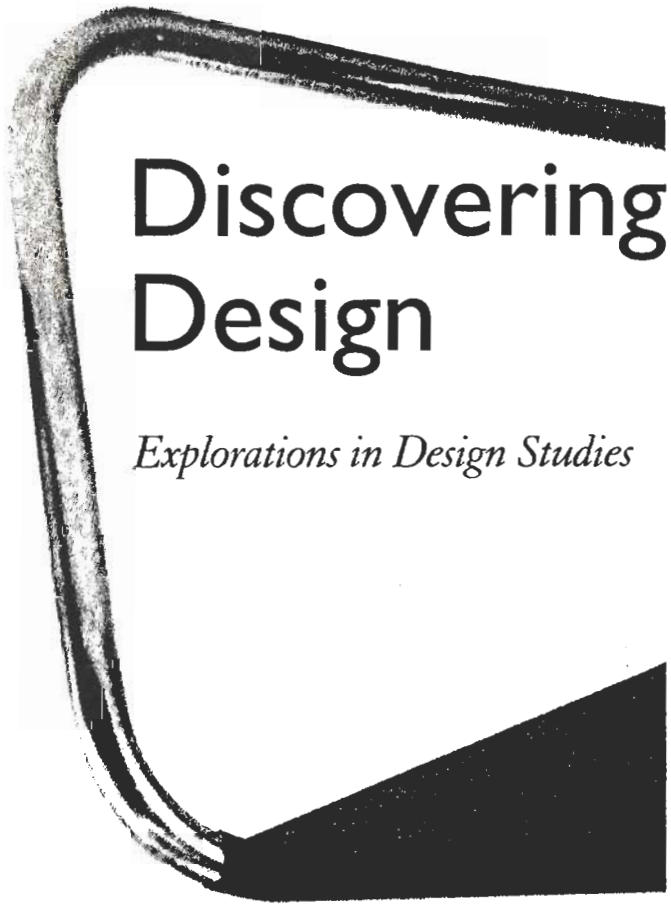

Discovering Design

Explorations in Design Studies

Edited by
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Contents

Editors' Note

Most of the essays selected for this volume were originally delivered as papers at an invited conference of the same name held at the University of Illinois, Chicago, on November 5–6, 1990. Funding for the conference, which was attended by twenty-five designers, design educators, and distinguished scholars and professionals representing a wide variety of fields, was provided by the university's Office of the Vice-Chancellor for Academic Affairs. The papers have since undergone extensive revision and expansion, based on discussions that began at the meeting. We have provided a conference summary as an appendix with information on the historical context of the meeting.

Richard Buchanan and Victor Margolin

Ethics into Design

Carl Mitcham

Ethics constitutes an attempt to articulate and reflect on guidelines for human activity and conduct. Logic is the attempt to articulate and reflect on guidelines for human thought. Both ethics and logic further develop theories about the most general principles and foundations of their respective guidelines. But what is it that articulates and reflects on guidelines for that intermediary between thought and action called design?[1]

As an English word, "design" is a modern derivate of the Latin *designare,* to mark or point out, delineate, contrive, by way of the French *désigner,* to indicate or designate, and can be defined as planning for action or miniature action.[2] It is remarkable, however, that neither Greek nor Latin contains any word that exactly corresponds to the modern word "design." The closest Greek comes to a word for "design" in the modern sense is perhaps *hupographein,* to write out. Much more common are simply *ennoein* (*en,* in + *noein,* to think) and *dianoein* (*dia,* through + *noein,* to think).

For the Greeks, human conduct can be ordered toward the production of material artifacts or nonmaterial goods, through

activities with ends outside themselves (*poieses,* makings), or it can be taken up with activities that are ends in themselves (*praxes,* doings). The pursuit of what is fitting in the domain of makings is discovered through *techne,* in the domain of doings, through *phronesis.* In one sense *phronesis* is only one among many virtues; in another it is the foundation of all virtue and thus coextensive with ethics.

Beyond the Greeks, planned making or doing—as distinct from simply intending to act, consideration of the ideals reflected or intended by different makings and doings, or the development of skills (*technai*) through practice—involves the systematic anticipatory analysis of human action. With regard to making, especially, such systematic anticipatory analysis entails miniature or modeled trial-and-error or experimental activity. In the modern context, this planning for making or miniature making, which was once severely restricted by both traditional frameworks and methodological limitations, has become the well-developed and dynamic activity of designing or design. The latter term can refer as well to the formal characteristics of the articulated plan or the static composition of the product brought forth by the scaled-up process that emerges from what has also been called "active contemplation."[3]

The modern attempt to reflect on designing or design has engendered primarily studies of the social or aesthetic quality of designed products and analyses of the logic or methodology of design processes. The thesis here is that both aesthetic criticism and the logic of design must be complemented by the introduction of ethics into design studies, in order to contribute to the development of a genuinely comprehensive philosophy of design.

On the Existence of Design

But if it is so important, why does ethics not already exist in design? The simple answer is that ethics was not needed within design until quite recently because until quite recently the activity known as designing did not play a prominent role in human affairs.

The most fundamental question regarding design—an ontological question, as it were—is this: Why is there design at all and not just nondesign? Certainly it is historically obvious that design

has not always been and therefore need not necessarily be. In nature, for instance, the design process does not occur. According to modern science, nature brings forth either by blind determination or by random change. Hence there arise debates about whether human beings as designers are part of nature, and whether the science of nature is able to be unified with the human sciences and humanities, not to mention theology. (The idea that God created the world "by design" is a unique conflation of Greek rationalism and Judeo-Christian-Islamic revelation.) Even on an Aristotelean account, to be "by *phusis,* nature" and "by *nomos,* convention" (if not design) constitute two distinct ways of being.

To be "by design" in any possible (weak) premodern sense typically denotes no more than affinity with that unique human reality, *nomos,* convention or custom, and *nous,* mind. Convention reified or in physical form is labeled artifice, that which has form not from within itself, like a rock or a tree, but from another, like a statue or a bed (see *Physics* 2, 1). Prior to the development of design as miniature making one could speak only of mental intention or static composition, thought or final material product, not any special or unique physical activity. The activity was simply making.

Vernacular human activity, especially vernacular making, insofar as it is restricted to traditional crafts, proceeds by intention but not necessarily by or through any systematic anticipatory analysis and modeling. Plato's shuttle maker looks to the form or idea of a shuttle and thereby does not have to design it (*Cratylus* 389a). Indeed, many central societal conventions and artifacts (e.g., traditional village customs and architectures) are, although human-made, not even the direct result of human intention.[4] (In the vernacular world, the "designing" actor is also one who proceeds with schemes, deviously, improperly.) What is most characteristic of nonmodern making activities are trial-and-error full-scale fabrication or construction, intuition and apprenticeship, techniques developed out of and guided by unarticulated and nondiscursive traditions and procedures. Reflection in relation to such making focuses more commonly on the symbolic character of results than on processes and methods of, say, efficiency in operation or production. To speak of design in crafts is to refer to something which is not yet, which occurs largely in unconscious or provisional forms—that is to say, design without

design. Yves Deforge in one attempt to write about such "design before design" calls these phenomena "avatars of design."[5]

Design as a protoactivity is manifest originally in the arts in the form of sketches for paintings. The unfinished chambers of Egyptian tombs reveal that drawings sometimes preceded finished murals. But for Vasari and his contemporaries, *disegno* or drawing and preparatory sketches are the necessary foundation of painting. The need for arguments in defense of this position reveals its special historical character. And there are at least two observations that can be ventured about such anticipatory activity in the artistic realm. First, it exhibits a continuity with that to which it leads. The tomb drawings are even the same size as the final mural that will follow; the Renaissance sketches develop skills that are repeated on canvas or wall. Second, conspicuous by its absence is any quantitative or input-output analysis. At the time of the Renaissance, however, design also appears in a distinctly modern form as the geometric construction of perspective, as a correlate of modern scientific naturalism, and as the precursor to engineering drawing.[6]

The distinctive feature of modern science as an activity rather than as a body of knowledge is experimental modeling. Through experimentation modern science constructs models of different natural processes, and by means of arguments based on a principle of proportionality uses them to reason from known cause-effect relations to unknown causes of known effects. Galileo was the pioneer of such modeling in physics (falling bodies), which has since been extended to chemistry (atomic models), biology (models of DNA), and even human psychology (computer modeling of cognitive processes).[7]

Modern scientific experimentation constructs models of what (it thinks) already exists, to expand knowing. The activity of design constructs models of what (it thinks) might be, to extend making. For science, models take in or receive and simplify complex phenomena, thereby disclosing order. For modern technology, or scientifically refined makings and usings in all their diversity, models project complex possibilities in realistic form, thus determining or enabling the control of power. When this projective modeling exhibits a conceptual break with the final result toward which it is pointed, a break to be bridged by analogy, it takes on its distinctly modern character.

Design models in engineering can, for instance, be "true" models, although more commonly they are merely "adequate" or even "distorted" and "dissimilar." As one engineer has put it, "A distorted model is [one] in which some design condition is violated sufficiently to require correction of the prediction equation. Under certain conditions, particularly where flow of fluids is involved, it is impracticable, if not impossible, to satisfy all of the design conditions [under a common scale]."[8] Likewise, "dissimilar models are models which bear no apparent resemblance to the prototype but which, through suitable analogies, give accurate predictions of the behavior of the prototype."[9] Another engineer distinguishes between models that are "totally direct," "totally indirect," "combination," "visual," and "competitive," with each being suited to test different aspects of a new idea.[10] All such models can be manifest in drawings, block diagrams, network schematics, mathematics, physical materials, and related systems of representation.[11]

Receptive, scientific modeling *embodies* knowledge; with regard to knowledge, embodiment necessarily entails simplifying *concepts*. Projective, technological modeling *disembodies* action; with regard to action, disembodiment that leaves *things* out, idealizes them. The former materializes, the later dematerializes. The paradoxical aim of projective, dematerialized or idealized modeling is not so much explanation as practical leverage, effectiveness. The present and its desires are cast with great force and power into the future.

Because of the complexity of variables, theory alone cannot be used to deduce, for instance, the shape of an airfoil, or to determine the optimum spatial arrangements of elements within a given structure. Engineers have to "figure out" such things by simulation, often employing a variety of models. So they construct a miniature, model airfoil and test it in a wind tunnel (now in a computer program); by means of such activities they are testing not some illustrated theory, but a represented artifact.[12] For structures, engineers create scaled-down floor plans or two-dimensional facades in order to play with alternative arrangements of shapes by means of sketched geometries or manipulated cutouts. In each case the model or mock-up constitutes a temporary reduction to be eventually scaled up in the production not of knowledge but of objects. Design uses created microscale cause-

effect relations rendered in models to engineer known or createable macroscale causes into the production of desirable or desired macroscale effects.[13]

On the Social Dimensions of Modern Design

As has been noted, for example by José Ortega y Gasset in his *Meditación de la técnica* (from lectures first delivered in 1933), traditional technics includes both the "invention of a plan of action"—which is not the same as a planning process—and the "execution of this plan."[14] Traditionally, both the formal-final and efficient causes remained within the mind and hand of the artisan. It is the modern separation of mental and manual, and the coordinate creation of inventor-engineer and worker, that grounds the original character of modern design. The two new categories of designing and working are not just thinking and making separated. Thinking and making are too inextricably conjoined in traditional craft for such a simple disjunction,[15] which is discerned only by critical abstraction. In the separation of intending and making are created instead an embodied, active form of intending (design) and a nonreflective but methodological form of making (labor).

This separation of formerly unified aspects of human experience is further coordinate with the becoming autonomous of a whole range of elements in human culture. Religion and politics are to be independent, likewise with art and religion and politics and science and education; all, along with economics as a kind of paradigm, become what Karl Polanyi terms "disembedded" from social life as a whole.[16] This separating and becoming independent of previously interwoven dimensions of a way of life constitutes, for Jürgen Habermas, the essence of the modern project.[17]

The emergence of disembedded and autonomous design constitutes as well a movement from vernacular to professional design, and has thus been variously defined by the two professions which claim it, engineers and artist-architects. The former commonly emphasize the quantitative, analytic, but iterative character of a multiphase process that includes preparatory and evaluative moments. The latter presents design as embodied, poetic thinking. Louis Bucciarelli, in "an ethnographic perspective," has described engineering design as a social process,[18] whereas

Richard Buchanan has argued for design as a kind of rhetoric. But what kind of social process? What form of rhetoric? What is to distinguish engineering and artistic design from the social process and rhetoric of politics? Whether engineering or architecture, accidentally reflecting social process or rhetoric, the defining activity is miniature making. For Bucciarelli this is found in a social process centering around distinct "object worlds"; for Buchanan it is a rhetoric of artifacts.

On the Ethics of Designing

Possibility and contingency are the fundamental ground of ethics. On the one hand, in the absence of any recognition of the possibility of some course of action, no ethical reflection is called for. On the other, if the course of action is strictly necessary, reflection can give rise only to theoretical explanation, not ethical judgment. One does not ask ethical questions of what cannot be or of what cannot be otherwise.

The historical discovery of design as systematic anticipatory analysis and modeling as a unique form of human action roughly contemporaneous with the rise of modern science and technology uncovers a new way of being in the world. The most fundamental ethical question concerning design is this: To what extent is this new way of being in the world desirable or good?

It is now common to recognize that, as Langdon Winner has said, technologies are "forms of life,"[19] or as Buchanan has put it, "design involves the vivid expression of competing ideas about social life."[20] But not only do different designs embody (implicitly or explicitly) distinct sociopolitical assumptions and visions of life, designing itself constitutes a new way of leading, or a leading into, different technological lifeworlds. Part of the unified newness of this way of leading into the techno-lifeworld, the activity or process of designing, can be indicated by noticing some difficulties or inadequacies of standard approaches to ethics in relation to it.

Consider, for example, what can be termed an ethics of correspondence, which judges action by the extent to which it is in harmony with or corresponds to what is already given by some pre-existing order. Common forms of such an ethics of correspondence are found in appeals to tradition or to natural law. The attempt to judge the design act as lawful or unlawful in accord with

the degree to which it harmonizes with and represents or opposes a tradition is contradicted by the core effort within design not to be guided by tradition, but to figure things out anew, to create new artifacts, to break with tradition. Modern design is traditional precisely to the extent that it opposes tradition.

Perhaps, then, one should adopt a deontological approach and consider the intentions of the designer or the principles of the design act in terms of consistency and universalizability. Indeed, as something less than full-bodied action, designing might well be compared to having an intention. Although many of its particular maxims may be open to serious challenge, it is difficult to see how the design process as a whole should not be inherently universalizable. Criticisms of modern technological design often focus on the inherent consistency, the rightness and wrongness, of various design maxims. But without the design process as a whole, how could one possibly address the problems inherent in the designed techno-lifeworld?

Nevertheless, as practice in miniature, design is something more than an intention. In however diminished a form, it is still physical activity. It is thus a busyness which, as such, does not encourage inner self-examination. Moreover, as physical activity, design is something that always has immediate physical consequences—even if they are, as it were, quite small, even minute. Its inner principle is the linking together of physical materials and energies in functional units to meet predetermined specifications, something to be worked out through models and testing. Design is inherently tipped toward action, is immanent activity, a protopragmatism.

Consider, then, an ethics of consequentialism, which would refer the moral character of action to the goodness or badness of its results. But the designing of an airfoil or a structure has no socially significant consequences. How could one calculate costs and utilities except in the most indirect terms? Probably most such designing leads nowhere, since the majority of designs never serve as a basis for full-scale construction. Design is more like a self-contained game. Its full-scale consequences, whatever they may be, occur only at secondary or tertiary removes—once the design serves as a basis for construction. A consequentialist judgment of designing readily strikes any designer as an abstract, far-fetched

focusing on remote contingencies into which an indefinite number of variables may intervene.

There are two further points that can be made about the difficulties of consequentialism. As Hannah Arendt has noted with regard to human action,[21] and as Hans Jonas has argued with regard to modern technology,[22] the remote consequences of activities are inherently difficult to predict. John Stuart Mill, anticipating such an argument, replies that the remote and unpredictable character of consequences can be mitigated by experience.[23] In more recent language, the difficulties of "act utilitarianism" can be met with "rule utilitarianism" grounded on common experience.[24] Human beings can learn that telling lies eventually has bad consequences most of the time. The problem with any appeal to experience in the case of modern design acts, however, is that insofar as designs are unique, their consequences are also continuously new. Principled change undermines the mitigating power of historical experience. (Could this account for the modern resistance to any reduction in the pace of technological change, and that continuously renewed optimism about design transformations that makes it so difficult to learn from failed experience and expectations?)

Yet the apparently diverse material products grounded in the new way of life defined by the principled pursuit of technological change through design do exhibit certain common features. Albert Borgmann has linked these together insightfully in what he terms the "device paradigm." Devices are to be contrasted with things. A thing, such as the fire-bearing hearth, entails bodily and social engagement. A device, such as a central heating unit, "procures mere warmth and disburdens us of all other elements." "Technological devices . . . have the function of procuring or making available a commodity such as warmth, transportation, or food . . . without burdening us in any way [by making them] commercially present, instantaneously, ubiquitously, safely, and easily."[25] The products of modern design are typically commodities that fit the device paradigm. Indeed, modern designing might even be described as "devising," the process of making present devices.

But devising and devices escape the reach of any full-bodied consequentialist criticism because of the apparently amorphous

neutrality or ambiguity of commodities, of deontological restriction because of the apparently inherent morality of its intention merely to make available without presupposition, and of the ethics of correspondence because of their principled rejection of corresponding to anything. Devices are neutral commodities. How, in themselves, could they be considered lawful or unlawful, right or wrong, good or bad, since they are designed to be nothing but pure receptivity to any law, right, or good? The thermostat, the light switch, the plastic bowl are simply available for use.

But if neither traditional correspondence nor deontologism nor consequentialism has any immediate purchase on designing, how is one to address the problems manifest in the new techno-lifeworld?

Two Versions of an Ethics in Design

Prescinding from any fundamental questioning of designing as a way of being in the world, it is still necessary to inquire about the presence of ethics in design. The modern systematic modeling of making—that is, design—has taken two distinct forms. One of these is technical, the other aesthetic. The former focuses on inner operational or functional relations within mechanical, chemical, electrical, and other artifacts and processes. The latter takes external appearance or composition as its concern. One evaluates its products in terms of the ideal of efficiency, striving with some minimal possible input of material and energy for a maximum output. The other seeks a formal concentration and depth of meaning.

To use less, engineers design increasingly complex but specialized objects devoid of decoration, although precisely because of their inner complexity the inner workings must be covered by some kind of decoration. To mean more, to become "charged and supercharged with meaning" (Ezra Pound), artists and architects render increasingly rich, ambiguous artifacts, textured and decorated in detail.

Each design tradition also develops its own professional ethos, which constitutes an implicit ethics of design. In engineering there has been a stress upon subordination, if not obedience and sameness.[26] In the arts the commitment is to independence and difference. Each brings to the fore complementary aspects of the

modern design experience: on the one hand, its authority and power: on the other, its revolution and independence. Extremes on both sides are reined in with appeals to responsibility.

The selective ethical responses to the problems summoned forth by the processes unleashed through modern design activity—from social disruption, dangerous machines, and anaesthetic consumer products to crowded and polluted urban environments—further reflect these two traditions. One stresses the need for more efficiency and argues for pushing forward toward increasingly extensive and systematic expansions of design, from time-and-motion studies to operations research and human factors engineering. The other calls attention to anomie, alienation, and cultural deterioration, and calls for either a turn toward the arts and crafts or the creative design of postmodern bricolage. The problems of "bad design" are viewed as caused either by insufficient design or by too much and the wrong kind.[27]

One tradition thus promotes methodological and empirical studies of engineering design processes; the other develops broad interpretative studies of the aesthetic and cultural dimensions of artifacts.[28] Aesthetic sensitivity meets the engineering mentality in industrial design and functionalism.[29] Engineering reaches out toward aesthetic criticisms with proposals for more socially conscious or holistic design programs.[30]

Both traditions depend on what may nevertheless be described as incomplete philosophical reflections. They uncritically seek either to export design methods across a whole spectrum of human activities or to import extraneous ideas into design. The proposal here is for the cultivated emergence of ethics within design as an effort to deepen the two traditions by moving from partial reflections and possible reforms to deeper understandings of the challenge of techno-lifeworld design and more comprehensive assessments of its problems.

Notes Toward an Inner Ethics of Design

According to Aristotle, the study of ethics depends on the practice of ethics (*Nichomachean Ethics* 1, 4; 1095b4–6). One cannot articulate and reflect on what one does not already have. Ethics cannot come from on high, as it were, to articulate guidelines for action. The attempt to cultivate ethics within design thus begins

with the attempt to articulate guidelines for that miniature action called designing such as they already exist. Only from here is it possible to move toward considerations of their adequacy, beginning perhaps with a recognition of special problems.

The fundamental ethical problem of design is created precisely by its principled separation from the inner and the outer worlds. It is not pure intention and part of an inner life, something that can be examined by means of self-reflection. Nor is it simply an overt action that readily calls for consequentialist evaluation. It is more like a game or play.

Indeed, in the premodern world, models functioned primarily as toys. Mayan toy carts and Alexandrian steam engines were never recast into the quotidian world as construction tools or industrial machines. With models one creates a provisionally self-contained or miniature world rather than thoughts that can be integrated into an inner life or actions that are part of everyday human affairs.

Models and their making thus easily take on a kind of independence, to constitute a phenomenon that demands evaluation on its own terms, whether technical or aesthetic. The inherent attractiveness of modern design activities lies not just in their potential utilitarian results but just as much in their technical beauties and beautiful techniques. Johan Huizinga, vulgarizing Friedrich Nietzsche and anticipating Jacques Derrida—the prophet and priest of postmodern culture—speaks for the modern attempt to find new values in the midst of the destruction of the old when he describes play as segregated from all "the great categorical antitheses": "Play lies outside the antithesis of wisdom and folly, and equally outside those of truth and falsehood, good and evil. . . . [I]t has no moral function. The valuations of vice and virtue do not apply here."[31]

The game, precisely because of what it is *qua* game, that is, a break from or setting aside of the world, asks not to be subject to the rules or judgments of the world. Children with dolls or with guns can behave in all sorts of ways that would not be acceptable were their toys people or weapons. A game of cards has its own rules, which are all that must be obeyed in order to be a "moral" card player. Clay modeling needs only to keep the clay wet enough to manipulate but not so wet as to run; otherwise it is wholly without rules.

Precisely because of its independence from and potential opposition to traditional morality, ethical reflection from Plato to the Puritans has argued for circumscribing and delimiting the world of play. Play at work, for instance, limits production and causes accidents. Playful sex readily degenerates into the promiscuous and pornographic.

Yet play need not be wholly rejected; it can also be delimited and preserved—perhaps in ways that maintain, even enhance, its very playfulness. Cut wholly free from any reference to the world, play can actually cease to be interesting. Pure play with words or numbers, as in *Finnegans Wake* or the higher reaches of mathematics, attracts fewer and fewer players and less and less of an audience. Under such situations it is appropriate to call for a revival of the relationship between play and life.

And insofar as play can be taken as a metaphor for design, this inner obligation that would preserve the activity from its own internal disintegration might be formulated as the following fundamental principle: "Remember the materials." "Return to real things." Do not let miniature making become so miniature that it ceases to reflect and engage the real world.

By way of attempting to elaborate on this suggestion, consider the following speculative observations:

1. The great temptation of any game is for it to become too self-contained, an activity of purely aesthetic pleasure or technical achievement. Insofar as all play becomes not a temporary separation from quotidian realities, but a pull away from life, it becomes subject to social criticism. The artist concerned only with form, the engineer concerned only with technical solutions—the pursuit of art for art's sake, engineering for the sake of engineer—can be challenged by more inclusive issues and social orders.

2. The human practice of designing simply as designing can be said to deepen the tendency inherent in all play by exhibiting a marked inclination to distance the designer from self-examination or social responsibility. Studies of the psychology and behavior of computer hackers dramatically confirm this point,[32] but it is one that is hinted at as well by the ethos of each design tradition. The engineering tradition of obedience and the avant-garde tradition of independence in the arts are but two expressions of disjunctions, from self and community.

3. Designing, unlike more limited forms of play, constitutes a

general pulling away from or bracketing of the world that can have immediate practical impact. The paradoxical strengths of the mathematization and modeling of modern design are that more effectively than ever before they separate from the world of experience *and* provide new levers for the technological manipulation of that world. Modern designing opens itself to being pulled back into the world beyond anything that designers themselves might imagine, desire, or plan. Hence, again, there exists a fundamental obligation to remember the materials, return to real things, and not let miniature making become so miniature that it ceases to reflect and engage the real world.

4. Perhaps nowhere is the challenge of remembering reality more important than in computer-aided design. Although tremendously powerful and attractive, computer-aided design is equally dangerous, precisely because even more than designing with pencil and paper against a background of practical experience with real-world artifacts, design with computers works in a rarefied medium with a facility that tends to deny the need for worldly experience. As Eugene Ferguson has argued, "To accomplish a design of any considerable complexity—a passenger elevator or a railroad locomotive or a large heat exchanger in an acid plant—requires a continuous stream of calculations, judgments, and compromises that should only be made by engineers experienced in the kind of system being designed. The 'big' decisions obviously should be based on intimate, firsthand, internalized knowledge of elevators, locomotives, or heat exchangers."[33]

5. But just as obviously, in a society in which elevators, locomotives, and heat exchangers are increasingly run by computers, and children rather than playing with trains play with train video games, it is difficult to cultivate an intimate, firsthand, internalized knowledge of anything real. Virtual experience is no substitute for real experience. The problems of design are not isolated in design. They are part of, even at one with, the larger culture as a whole. To return to real things is a challenge throughout the ways of life characteristic of postmodern society.

6. The real experience of struggling to return to real things taking ethics beyond fundamental principles into specific cases will be the basis for development of a *phronesis* of the technolifeworld.

The problems with design are not just technical or aesthetic, but also ethical. Indeed, introducing ethics into design revels the deepest aspects of our difficulties. But the difficulties we face cannot begin to be addressed without clear-sightedness. To attempt to recognize them is itself to struggle for the right and the good.[34]

Notes

1. For a different but related notion of the intermediary character of design, see C. Wright Mills, "Man in the Middle: The Designer," in *Power, Politics, and People: The Collected Essays of C. Wright Mills,* ed. Irving Louis Horowitz (New York: Oxford University Press, 1963), pp. 374–86.

2. Aspects of this definition are first developed in Carl Mitcham, "Types of Technology," *Research in Philosophy and Technology* 1 (1978): 245–48. It is further elaborated in slightly different ways in "Engineering as Productive Activity: Philosophical Remarks," *Critical Perspectives on Non-Academic Science and Engineering,* ed. Paul T. Durbin (Bethlehem, PA: Lehigh University Press, 1991), pp. 96ff., and *Thinking through Technology: The Path between Engineering and Philosophy* (Chicago: University of Chicago Press, 1994), pp. 220ff.

3. Richard Buchanan, "Declaration by Design: Rhetoric, Argument, and Demonstration in Design Practice," in *Design Discourse: History, Theory, Criticism,* ed. Victor Margolin (Chicago: University of Chicago Press, 1989), pp. 98, 103.

4. See F. A. Hayek, "The Results of Human Action But Not of Human Design," in his *Studies in Philosophy, Politics, and Economics* (Chicago: University of Chicago Press, 1967), pp. 96–105. Hayek uses "design" in the weak sense as equivalent with intention.

5. Yves Deforge, "Avatars of Design: Design before Design," *Design Issues* 6, no. 2 (Spring 1990): 43–50.

6. On the last point, see Peter Jeffrey Booker, *A History of Engineering Drawing* (London: Chatto and Windus, 1963).

7. Key studies of the role of model construction in modern science can be found in Mary B. Hesse, *Models and Analogies in Science* (Notre Dame: University of Notre Dame Press, 1966); Rom Harre, *The Principles of Scientific Thinking* (Chicago: University of Chicago Press, 1970); and William A. Wallace, "The Intelligibility of Nature: A Neo-Aristotelian View," *Review of Metaphysics* 38, no. 1, whole no. 149 (Sept. 1984): 33–56.

8. Glenn Murphy, *Similitude in Engineering* (New York: Ronald, 1950), p. 61.

9. *Ibid.,* pp. 61–62.

10. Gordon L. Glegg, *The Development of Design* (Cambridge: Cambridge University Press, 1981), pp. 44–45.

11. See William H. Middendort, *Design of Devices and Systems* (New York: Dekker, 1986), pp. 156ff. (Note, in passing, that the positive connotations of "schematic representation" build on while transforming the traditional negative implications of a "scheme.")

12. For more on this point, see Walter G. Vincenti, *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History* (Baltimore: Johns Hopkins University Press, 1990).

13. For an extended discussion of the dimensional problems engendered by such modeling, see Stephen J. Kline, *Similitude and Approximation Theory* (New York: McGraw-Hill, 1965).

14. José Ortega y Gasset, *Meditación de la técnica* (originally published 1939), in *Obras Completas,* vol. 5 (Madrid: Alianza and Revista de Occidente, 1983), p. 365.

15. See Andrew Harrison, *Making and Thinking: A Study of Intelligent Activities* (Indianapolis: Hackett, 1978).

16. See Karl Polanyi, "Aristotle Discovers the Economy," in Karl Polanyi, Conrad M. Arensberg, and Harry W. Pearson, *Trade and Market in the Early Empires: Economics in History and Theory* (Glencoe, IL: Free Press, 1957), pp. 64–94.

17. See, e.g., Jürgen Habermas, "Modernity—An Incomplete Project," in *The Anti-Aesthetic: Essays on Postmodern Culture,* ed. Hal Foster (Port Townsend, WA: Bay Press, 1983), pp. 3–15.

18. Louis L. Bucciarelli, "An Ethnographic Perspective on Engineering Design," *Design Studies* 9, no. 3 (July 1988): 159–68.

19. Langdon Winner, "Technologies as Forms of Life," in *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago: University of Chicago Press, 1986), pp. 3–18.

20. Richard Buchanan, "Declaration by Design," p. 94.

21. See Hannah Arendt, *The Human Condition* (Chicago: University of Chicago Press, 1958), especially chapters 32–34.

22. See Hans Jonas, *The Imperative of Responsibility: In Search of an Ethics for the Technological Age,* trans. H. Jonas and David Herr (Chicago: University of Chicago Press, 1984), particularly chapter 1, "The Altered Nature of Human Action." For further analysis extending the ideas of both Arendt and Jonas, see Barry Cooper, *Action into Nature: An Essay on the Meaning of Technology* (Notre Dame: University of Notre Dame Press, 1991).

23. John Stuart Mill, *Utilitarianism* (1861), chapter 1, near the end.

24. See William K. Frankena, *Ethics,* 2nd ed (Englewood Cliffs, NJ: Prentice-Hall, 1973), pp. 35ff.

25. Albert Borgmann, *Technology and the Character of Contemporary Life: A Philosophical Inquiry* (Chicago: University of Chicago Press, 1984), pp. 42, 77.

26. For more on this tradition, see Carl Mitcham, "Schools for Whistle Blowers: Educating Ethical Engineers," *Commonweal* 114, no. 7 (April 10, 1987): 201–5.

27. For a good brief survey of the literature of these two traditions, see Victor Margolin, "Postwar Design Literature: A Preliminary Mapping," in *Design Discourse,* ed. Margolin, pp. 265–87.

28. See, e.g., in the first instance, M. J. de Vries, N. Cross, and D. P. Grant, eds., *Design Methodology and Relationships with Science* (Boston: Kluwer, 1993); and in the second, John Thackara, ed., *Design after Modernism: Beyond the Object* (New York: Thames and Hudson, 1988).

29. See, e.g., Herbert Lindinger, ed., *Ulm Design: The Morality of Objects,* trans. David Britt (Cambridge, Mass.: MIT Press, 1991).

30. See, e.g., Victor Papanek, *Design for Human Scale* (New York: Van Nostrand, 1983), and *Design for the Real World: Human Ecology and Social Change,* 2nd ed. (New York: Van Nostrand Reinhold, 1984).

31. Johan Huizinga, *Homo Ludens: A Study of the Play-Element in Culture* (Boston: Beacon, 1955), p. 6.

32. See, e.g., Sherry Turkle, *The Second Self: Computers and the Human Spirit* (New York: Simon and Schuster, 1984), especially chapter 4.

33. Eugene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge, MA: MIT Press, 1992), p. 37.

34. This paper owes improvement, though still no doubt not enough, to critical comments from Tim Casey (University of Scranton).