Designerly Ways of Knowing: Design Discipline Versus Design Science

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Design and Science

I would like to begin this paper with a brief review of some of the historical concerns that have emerged with respect to the relationship between design and science. These concerns emerged strongly at two important periods in the modern history of design: in the 1920s, with a search for scientific design products, and in the 1960s, with a concern for scientific design process. The 40-year cycle in these concerns appears to be coming around again, and we might expect to see the reemergence of design-science concerns in the 2000s.

A desire to "scientise" design can be traced back to ideas in the twentieth century modern movement of design. For example, in the early 1920s, the *De Stijl* protagonist, Theo van Doesburg, expressed his perception of a new spirit in art and design: "Our epoch is hostile to every subjective speculation in art, science, technology, etc. The new spirit, which already governs almost all modern life, is opposed to animal spontaneity, to nature's domination, to artistic flummery. In order to construct a new object we need a method, that is to say, an objective system." [1] A little later, the architect Le Corbusier wrote about the house as an objectively designed "machine for living:" "The use of the house consists of a regular sequence of definite functions. The regular sequence of these functions is a traffic phenomenon. To render that traffic exact, economical, and rapid is the key effort of modern architectural science." [2] In both comments, and throughout much of the modern movement, we see a desire to produce works of art and design based on objectivity and rationality, that is, on the values of science.

These aspirations to scientise design surfaced strongly again in the "design methods movement" of the 1960s. The Conference on Design Methods, held in London in September, 1962 [3] generally is regarded as the event which marked the launch of design methodology as a subject or field of inquiry. The desire of the new movement was even more strong than before to base design process (as well as the products of design) on objectivity and rationality. The origins of this emergence of new design methods in the 1960s lay in the application of novel, scientific, and computational methods to the novel and pressing problems of the Second World War—from

1 T. van Doesberg, "Towards a Collective Construction," ***De Stijl*** (1923) (Quoted by G. Naylor, ***The Bauhaus,*** London: Studio Vista, 1968).

2 Le Corbusier, ***CIAM 2nd Congress***, Frankfurt (1929).

3 J. C. Jones and D. G. Thornley, eds., ***Conference on Design Methods*** (Oxford: Pergamon, 1963).

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which came civilian developments such as operations research and management decision-making techniques.

The 1960s was heralded as the "design science decade" by the radical technologist Buckminster Fuller, who called for a "design science revolution" based on science, technology, and rationalism to overcome the human and environmental problems that he believed could not be solved by politics and economics.[4] From this perspective, the decade culminated with Herbert Simon's outline of "the sciences of the artificial," [5] and his specific plea for the development of "a science of design" in the universities: "a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process."

However, in the 1970s, there emerged a backlash against design methodology and a rejection of its underlying values, notably by some of the early pioneers of the movement. Christopher Alexander, who had originated a rational method for architecture and planning,[6] now said: "I've disassociated myself from the field... There is so little in what is called "design methods" that has anything useful to say about how to design buildings that I never even read the literature anymore... I would say forget it, forget the whole thing." [7] Another leading pioneer, J. Christopher Jones, said: "In the 1970s, I reacted against design methods. I dislike the machine language, the behaviorism, the continual attempt to fix the whole of life into a logical framework. [8]

To put the quotations of Alexander and Jones into context, it may be necessary to recall the social/cultural climate of the late-1960s—the campus revolutions and radical political movements, the new liberal humanism, and the rejection of conservative values. But also it had to be acknowledged that there had been a lack of success in the application of "scientific" methods to everyday design practice. Fundamental issues also were raised by Rittel and Webber,[9] who characterized design and planning problems as "wicked" problems, fundamentally unamenable to the techniques of science and engineering, which dealt with "tame" problems.

Nevertheless, design methodology continued to develop strongly, especially in engineering and some branches of industrial design. (Although there may still have been very limited evidence of practical applications and results.) The fruits of this work emerged in a series of books on engineering design methods and methodology in the 1980s. English-language ones included Tjalve,[10] Hubka,[11] Pahl and Beitz,[12] French,[13] Cross,[14] and Pugh.[15]

Another significant development throughout the 1980s and into the 1990s was the emergence of new journals of design research, theory, and methodology. Again, English-language publications included *Design Studies* in 1979, *Design Issues* in 1984, *Research in Engineering Design* in 1989, the *Journal of Engineering Design* and the *Journal of Design Management* in 1990, *Languages of Design* in 1993, and the *Design Journal* in 1997.

4 B. Fuller, ***Utopia or Oblivion*** (New York: Bantam Books, 1999).

5. H. A. Simon, ***The Sciences of the Artificial*** (Cambridge, MA: MIT Press, 1969).

6. C. Alexander, ***Notes on the Synthesis of Form*** (Harvard University Press, 1964).

7 C. Alexander, "The State of the Art in Design Methods," ***DMG Newsletter*** 5:3 (1971).

8 J. C. Jones, "How My Thoughts About Design Methods Have Changed During the Years," ***Design Methods and Theories*** 11:1 (1977).

9 H. Rittel and M. Webber, "Dilemmas in a General Theory of Planning," ***Policy Sciences*** 4 (1973): 155-69.

10 E. Tjalve, ***A Short Course in Industrial Design*** (London: Newnes-Butterworth, 1979).

11 V. Hubka, ***Principles of Engineering Design*** (Guildford: Butterworth, 1982).

12 G. Pahl and W. Beitz, ***Engineering Design*** (London: Springer/Design Council, 1984).

13 M. J. French, ***Conceptual Design for Engineers*** (London: Design Council, 1985).

14 N. Cross, ***Engineering Design Methods*** (Chichester: Wiley, 1989).

15 S. Pugh, ***Total Design: Integrated Methods for Successful Product Engineering*** (Workingham: Addison-Wesley, 1991).

Despite the apparent scientific basis (and bias) of much of their work, design methodologists also sought from the earliest days to make distinctions between design and science, as reflected in the following quotations.

> Scientists try to identify the components of existing structures, designers try to shape the components of new structures.
> —Alexander [6]

> The scientific method is a pattern of problem-solving behavior employed in finding out the nature of what exists, whereas the design method is a pattern of behavior employed in inventing things...which do not yet exist. Science is analytic; design is constructive.
> —Gregory [16]

> The natural sciences are concerned with how things are...design on the other hand is concerned with how things ought to be.
> —Simon [5]

There may indeed be a critical distinction to be made: method may be vital to the practice of science (where it validates the results), but not to the practice of design (where results do not have to be repeatable, and, in most cases, must *not* be repeated, or copied). The Design Research Society's 1980 conference on "Design: Science: Method" [17] provided an opportunity to air many of these considerations. The general feeling from that conference was, perhaps, that it was time to move on from making simplistic comparisons and distinctions between science and design; that perhaps there was not so much for design to learn from science after all, and that perhaps science rather had something to learn from design. Cross et al.[18] claimed that the epistemology of science was, in any case, in disarray and, therefore, had little to offer an epistemology of design. Glynn[19] later suggested that "It is the epistemology of design that has inherited the task of developing the logic of creativity, hypothesis innovation, or invention that has proved so elusive to the philosophers of science."

Despite several attempts at clarification (see de Vries, Cross, and Grant [20]), there remains some confusion about the design-science relationship. Let us at least try to clarify three different interpretations of this concern with the relationship between science and design: (a) scientific design, (b) design science, and (c) a science of design.

Scientific Design

As I noted above, the origins of design methods lay in "scientific" methods, similar to decision theory and the methods of operational

16 S. Gregory, "A Design Science," in S. A. Gregory, ed., ***The Design Method*** (London: Butterworth, 1966).

17 R. Jacques and J. Powell, eds., ***Design:Science:Method*** (Guildford: Westbury House, 1981).

18 N. Cross, J. Naughton, and D. Walker, "Design Method and Scientific Method," in R. Jacques and J. Powell, eds., ***Design:Science:Method,*** (Guildford: Westbury House, 1981).

19 S. Glynn, "Science and Perception as Design," ***Design Studies*** 6:3 (1985).

20 M. de Vries, N. Cross, and D. Grant, eds., ***Design Methodology and Relationships With Science*** (Dordrecht: Kluwer, 1993).

research. The originators of the "design methods movement" also realized that there had been a change from the craftwork of pre-industrial design to the mechanization of industrial design—and perhaps some even foresaw the emergence of a post-industrial design. The reasons advanced for developing new methods often were based on the assumption that modern, industrial design had become too complex for intuitive methods.

The first half of the twentieth century had seen the rapid growth of scientific underpinnings in many types of design—e.g., materials science, engineering science, building science, and behavioral science. One view of the design-science relationship is that, through this reliance of modern design upon scientific knowledge, and through the application of scientific knowledge in practical tasks, design "makes science visible." [21]

So we might agree that *scientific design* refers to modern, industrialized design—as distinct from pre-industrial, craft-oriented design-based on scientific knowledge but utilizing a mix of both intuitive and nonintuitive design methods. "Scientific design" is probably not a controversial concept, but merely a reflection of the reality of modern design practice.

Design Science

"Design Science" was a term perhaps first used by Buckminster Fuller, but it was adapted by Gregory [16] into the context of the 1965 conference on "The Design Method." The concern to develop a design science thus led to attempts to formulate *the* design method—a coherent, rationalized method, as "the scientific method" was supposed to be. Others, too, have had the development of a "design science" as their aim; for example, Hubka and Eder,[22] originators of the *Workshop Design Konstruction* (WDK) and a major, continuing series of international conferences on engineering design (ICED), also formed "The International Society for Design Science." Hansen[23] had stated the aim of design science as being to "recognize laws of design and its activities, and to develop rules." This would seem to be design science constituted simply as "systematic design"—the procedures of designing organized in a systematic way. Hubka and Eder regard this as a narrower interpretation of design science than their own: "Design science comprises a collection (a system) of logically connected knowledge in the area of design, and contains concepts of technical information and of design methodology.... Design science addresses the problem of determining and categorizing all regular phenomena of the systems to be designed, and of the design process. Design science also is concerned with deriving from the applied knowledge of the natural sciences appropriate information in a form suitable for the designer's use." This definition extends beyond "scientific design," in including systematic knowledge of design process and methodology, as well as the scientific/technological underpinnings of the design of artifacts.

21 R. A. Willem, "Design and Science," ***Design Studies*** 11:1 (1990).

22 V. Hubka and W. E. Eder "A Scientific Approach to Engineering Design," ***Design Studies*** 8:3 (1987).

23 F. Hansen, ***Konstruktionswissenschaft*** (Munich: Carl Hanser, 1974).

So we might conclude that *design science* refers to an explicitly organized, rational, and wholly systematic approach to design; not just the utilization of scientific knowledge of artifacts, but design in some sense as a scientific activity itself. This certainly is a controversial concept, challenged by many designers and design theorists. As Grant [24] wrote:

> Most opinion among design methodologists and among designers holds that the act of designing itself is not and will not ever be a scientific activity; that is, that designing is itself a nonscientific or ascientific activity.

Science of Design

However, Grant also made it clear that "the study of designing may be a scientific activity; that is, design as an activity may be the subject of scientific investigation." There remains some confusion between concepts of design science and of a science of design, since a "science of design" seems to imply (or, for some people, has the goal of) the development of a "design science." But the concept of a science of design has been clearly stated by Gasparski and Strzalecki: [25]

> The science of design (should be) understood, just like the science of science, as a federation of subdisciplines having design as the subject of their cognitive interests.

In this latter view, therefore, the science of design is the *study* of design—something similar to what I have elsewhere defined as "design methodology"; the study of the principles, practices, and procedures of design. For me, design methodology "includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems." [26] The *study* of design leaves open the interpretation of the *nature* of design.

So let me suggest here that the *science of design* refers to that body of work which attempts to improve our understanding of design through "scientific" (i.e., systematic, reliable) methods of investigation. And let us be clear that a "science of design" is not the same as a "design science."

Design as a Discipline

Donald Schön [27] explicitly challenged the positivist doctrine underlying much of the "design science" movement, and offered instead a constructivist paradigm. He criticized Simon's view of a "science of design" for being based on approaches to solving well-formed problems, whereas professional practice throughout design and technology and elsewhere has to face and deal with "messy, problematic situations." Schön proposed, instead, to search for "an epis-

24 D. Grant, "Design Methodology and Design Methods," ***Design Methods and Theories*** 13:1 (1979).

25 W. Gasparski and A. Strzalecki, "Contributions to Design Science: Praxeological Perspective," ***Design Methods and Theories*** 24: 2 (1990).

26 N. Cross, ***Developments in Design Methodology*** (Chichester: Wiley, 1984).

27 D. Schön, ***The Reflective Practitioner*** (London: Temple-Smith, 1983).

temology of practice implicit in the artistic, intuitive processes which some practitioners do bring to situations of uncertainty, instability, uniqueness, and value conflict," and which he characterized as "reflective practice." Schön appeared to be more prepared than his positivist predecessors to put trust in the abilities displayed by competent practitioners, and to try to explicate those competencies rather than to supplant them. This approach particularly has been developed in a series of conferences and publications throughout the 1990s in "design thinking research": Cross et al.,[28, 29] Akin,[30] and Goldschmidt and Porter.[31]

Despite the positivist, technical-rationality basis of *The Sciences of the Artificial*, Simon did propose that "the science of design" could form a fundamental, common ground of intellectual endeavor and communication across the arts, sciences, and technology. What he suggested was that the study of design could be an interdisciplinary study accessible to all those involved in the creative activity of making the artificial world. For example, Simon wrote that "Few engineers and composers... can carry on a mutually rewarding conversation about the content of each other's professional work. What I am suggesting is that they can carry on such a conversation about design, can begin to perceive the common creative activity in which they are both engaged, and can begin to share their experiences of the creative, professional design process." I believe that this is what we have been seeing in the development of interdisciplinary design studies in our journals and conferences.

Design as a discipline, therefore, can mean design studied on its own terms, and within its own rigorous culture. It can mean a science of design based on the reflective practice of design: design as a discipline, but not design as a science. This discipline seeks to develop domain-independent approaches to theory and research in design.[32] The underlying axiom of this discipline is that there are forms of knowledge special to the awareness and ability of a designer, independent of the different professional domains of design practice.

What designers especially know about is the "artificial world"—the human-made world of artifacts. What they especially know how to do is the proposing of additions to and changes to the artificial world. Their knowledge, skills, and values lie in the techniques of the artificial. (Not "the sciences of the artificial.") So design knowledge is of and about the artificial world and how to contribute to the creation and maintenance of that world. Some of it is knowledge inherent in the activity of designing, gained through engaging in and reflecting on that activity. Some of it is knowledge inherent in the artifacts of the artificial world (e.g., in their forms and configurations—knowledge that is used in copying from, reusing or varying aspects of existing artifacts), gained through using and reflecting upon the use of those artifacts. Some of it is knowledge inherent in the processes of manufacturing the artifacts,

28 N. Cross, K. Dorst, and N. Roozenburg, eds., ***Research in Design Thinking*** (Delft: Delft University Press, 1992).

29 N. Cross, H. Christiaans, and K. Dorst, eds., ***Analysing Design Activity*** (Chichester: Wiley, 1996).

30 O. Akin, ed., "Descriptive Models of Design Activity," ***Design Studies*** 18:4 (1997).

31 G. Goldschmidt and W. Porter, eds., ***4th Design Thinking Research Symposium*** (Cambridge, MA: MIT Press, 1999).

32 N. Cross, "Design Research: A Disciplined Conversation," ***Design Issues*** 15:2 (1999).

gained through making and reflecting upon the making of those artifacts. And some of each of these forms of knowledge also can be gained through instruction in them.

Just as the other intellectual cultures in the sciences and the arts concentrate on the underlying forms of knowledge peculiar to the scientist or the artist, so we must concentrate on the "designerly" ways of knowing, thinking, and acting.[33, 34] Following Schön and others, many researchers in the design world have realized that design practice does indeed have its own strong and appropriate intellectual culture, and that we must avoid swamping our design research with different cultures imported either from the sciences or the arts. This does not mean that we should completely ignore these other cultures. On the contrary, they have much stronger histories of inquiry, scholarship, and research than we have in design. We need to draw upon those histories and traditions where appropriate, while building our own intellectual culture, acceptable and defensible in the world on its own terms. We have to be able to demonstrate that standards of rigor in our intellectual culture at least match those of the others.

33 N. Cross, "Designerly Ways of Knowing," ***Design Studies*** 3:4 (1982).

34 N. Cross, "Natural Intelligence in Design," ***Design Studies*** 20:1 (1999).