Revisiting Herbert Simon's "Science of Design"

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Herbert A. Simon's *The Sciences of the Artificial* has long been considered a seminal text for design theorists and researchers anxious to establish both a scientific status for design and the most inclusive possible definition for a "designer," embodied in Simon's oft-cited "[e]veryone designs who devises courses of action aimed at changing existing situations into preferred ones."[1] Similar to the earlier Design Methods movement, which defines design as a problem solving, process-oriented activity (rather than primarily concerned with the production of physical artifacts), Simon's "science of design" was part of his broader project of unifying the social sciences with problem solving as the glue. This article revisits Simon's ideas about design both to place them in context and to question their ongoing legacy for design researchers. Much contemporary design research, in its pursuit of academic respectability, remains aligned to Simon's broader project, particularly in its definition of design as "scientific" problem solving. However, the repression of judgment, intuition, experience, and social interaction in Simon's "logic of design" has had, and continues to have, profound implications for design research and practice.

Cold War Problem Solving and the Military-Industrial-Academic Complex

Simon's path to *The Sciences of the Artificial* is worth sketching to contextualize its theoretical framework. Simon's undergraduate education in the 1930s at the University of Chicago was an important foundation; he studied there with logical positivist philosopher Rudolf Carnap and economist Henry Schultz before he began a doctorate in political science.[2] What was later dubbed the "Chicago School" of political science—led by Charles Merriam, Chair of the Political Science Department—became Simon's first intellectual home, and it was founded on the idea that scientific method could solve problems of social research. As opposed to a political science based in law or history, Merriam championed a political science that drew on the quantitative practices of natural science, including systematic observation, research labs, and the use of mathematics and statistics.[3] Beyond purely theoretical research, Merriam also

1 Herbert A. Simon, *The Sciences of the Artificial,* 3rd ed. (Cambridge, MA: MIT Press, 1996): 111. Design research review articles typically start with Simon's text as foundational. See, for example, Nigel Cross, "Editorial: Forty Years of Design Research," *Design Studies* 28, no. 1 (January 2007): 1–4; and Nigan Bayazit, "Investigating Design: A Review of Forty Years of Design Research," *Design Issues* 20, no. 1 (Winter 2004): 16–29.

2 See Hunter Crowther-Heyck, *Herbert A. Simon: The Bounds of Reason in Modern America* (Baltimore: Johns Hopkins University Press, 2005), especially Chapter 2, "The Chicago School and the Sciences of Control," 31–59.

3 Michael T. Heaney and John Mark Hansen argue that the idea of a unified, systematic social science championed by Merriam in the 1920s and 1930s, owes a debt to John Dewey, professor at University of Chicago from 1894 to 1904. (Mark T. Heaney and John Mark Hansen, "Building the Chicago School," *American Political Science Review* 100, no. 4, (2006): 589–96.) Connections with pragmatist philosophy at University of Chicago; also through Dewey's colleague George Herbert Mead who worked there until his death in 1931, although beyond the scope of this article, warrant further study.

had a practical agenda, as he revealed in *New Aspects of Politics:* "Have we not reached the time, when it is necessary to adjust and adapt more intelligently, to apply the categories of science to the vastly important forces of social and political control?"[4] The interdisciplinary research culture at the University of Chicago, founded on objectivity and faith in scientific methods, remained central to Simon's later work. Reflecting on this period, Simon later recalled, the "social sciences, I thought, needed the same kind of rigor and the same mathematical underpinnings that had made the 'hard' sciences so brilliantly successful."[5] He would also continue Merriam's mission of applying this scientific rigor to social actions and processes, including design.

Prompted by his participation in the Cowles Commission for Research in Economics seminars in the late 1940s, Simon described the excitement of interdisciplinary research in new areas (i.e., management theory, game theory, information theory, cybernetics, and statistical decision theory): "The ideas were all closely intertwined, with decision making at their core, and they quickly generated a scientific culture—an interlocking network of scientists with a real sense of community."[6] Evangelical in applying scientific methods to new professions, Simon's initial contributions were in management fields, but he soon worked fluidly across disciplines. In his first book, *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organization,* published in 1947, Simon developed a framework based on decision making that re-conceptualized the description and analysis of bureaucratic organizations. He also outlined the key theme of his future research in the book's introduction: the problem of "the process of choice which leads to action."[7]

Simon's interest in decision making and management continued after he moved to Carnegie Institute of Technology (later Carnegie Mellon University) in 1949. There, he helped found the new Graduate School of Industrial Administration (GSIA). The GSIA, an institute devoted to interdisciplinary research based on empiricism, mathematical rigor, and behavioral psychology—with decision making at its core—had a major effect on later management education and research.[8] Simon remained at Carnegie Mellon as Professor of Computer Science and Psychology, and, after winning the 1978 Nobel Prize for Economics, he was claimed by both computer scientists and psychologists as "our Nobel prize winner."[9]

By the 1950s, Simon was well positioned to take full advantage of the wealth of post-war research grants. The research patronage regime that thrived until the mid-1960s included private foundations (e.g., Ford, Carnegie, and Rockefeller Foundations), military institutes (e.g., RAND, the Office of Naval Research, the Air Force Office of Scientific Research, and the Army's Operations Research Office), and government bodies (e.g., the National Institutes of Health). These foundations and institutes were tightly

4   Charles E. Merriam, *New Aspects of Politics* (Chicago: University of Chicago Press, 1925): x. Simon reflects on Merriam's legacy in a 1985 lecture, "Charles E. Merriam and the 'Chicago School' of Political Science," available online at the Carnegie Mellon University Digital Collections, Herbert Simon Collection: http://digitalcollections.library.cmu.edu/awweb/awarchive?type=file&item=34043 (accessed April 28, 2014).

5   Herbert A. Simon, "Autobiography," www.nobelprize.org/nobel_prizes/economics/laureates/1978/simon.html (accessed April 28, 2014).

6   Herbert A. Simon, *Models of My Life* (New York: Basic Books, 1991): 107.

7   Herbert A. Simon, *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations,* Fourth Edition (New York: The Free Press, 1997): 1.

8   See Hunter Heyck, "Producing Reason" in *Cold War Social Science: Knowledge Production, Liberal Democracy, and Human Nature,* Mark Solovey and Hamilton Cravens, eds. (New York: Palgrave Macmillan, 2012): 99–115; and on the GSIA specifically, see Hunter Crowther-Heyck, "Herbert Simon and the GSIA: Building an Interdisciplinary Community," *Journal of the History of the Behavioral Sciences* 42, no. 4 (Autumn 2006): 311–34.

9   Edward A. Feigenbaum, "Herbert Simon: 1916–2001. Retrospective," *Science* 291, no. 5511 (March 16, 2001): 2107.

10 Hunter Crowther-Heyck, "Patrons of the Revolution: Ideas and Institutions in Postwar Behavioral Science," *Isis* 97, no. 3 (September 2006): 431. See also Joel Isaacs, who adds Talcott Parsons as another "scientific broker" (Joel Isaacs, "Tangled Loops: Theory, History and the Human Sciences in Modern America," *Modern Intellectual History* 6, no. 2 (August 2009): 398.

11 Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993): 1. Although military funding decreased over the 1960s and 1970s, partly due to the rise in funding through the National Science Foundation, NASA, and National Institutes of Health, it rose again in the 1980s.

12 Leslie, *The Cold War and American Science,* 2. See also Herbert I. Schiller and Joseph Dexter Phillips, eds., *Super State: Readings in the Military-Industrial Complex* (Chicago: University of Chicago Press, 1970). Simon noted that both RAND and the Cowles Commission were central to the quantitative "revolution" in American Social Sciences. (Simon, *Models of My Life*, 116).

13 Roger E. Levien, "RAND, IIASA and the Conduct of Systems Analysis," in *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After*, Agatha C. Hughes and Thomas P. Hughes, eds. (Cambridge, MA: The MIT Press, 2000): 446.

14 Esther-Mirjam Sent, "Herbert A. Simon as a Cyborg Scientist," *Perspectives on Science* 8, no. 4 (Winter 2000): 391.

15 Agatha C. Hughes and Thomas P. Hughes, "Introduction," in Hughes and Hughes, *Systems, Experts, and Computers*, 2.

interconnected through a handful of key intellectual entrepreneurs or "brokers" who served as program directors and on advisory councils. Historian Hunter Crowther-Heyck argues that "brokers like [Merrill] Flood and Simon helped build a patronage system with a coherent set of goals: specifically, to promote research that was *mathematical, behavioral-functional, problem-centered, and interdisciplinary.*"[10] Although various foundations sponsored his research, Simon's problem-solving research was particularly indebted to his consultancy and collaborations at the RAND Corporation during the 1950s and 1960s.

Established by the Air Force following World War II, Project RAND (Research ANd Development) became the Santa Monica-based RAND Corporation in 1948. During the 1950s and 1960s—an era in which "the Department of Defense (DOD) became the biggest single patron of American science"[11]—RAND was a particularly influential "think tank" that helped define American military strategy during the Cold War, including developing the policy of nuclear deterrence by "Mutually Assured Destruction." In a convergence described later as the "military-industrial-academic complex," many American intellectuals provided basic research for the defense industry during the Cold War.[12] By the 1960s, "RAND's roster of consultants numbered over 500" of America's brightest intellects, including mathematicians John von Neumann and Albert Wohlstetter, economist Kenneth Arrow, and Simon's future collaborator, Allen Newell, all attracted to the interdisciplinary research environment free from academic burdens.[13] However, RAND's research had a specifically military agenda and its problems included "launching and orbiting satellites, using atomic fission in airplane propulsion, maximizing the performance of airplanes, developing titanium and other advanced materials, and evaluating the damaging effects of nuclear bombs."[14] Research programs were organized under areas of interest for the Air Force, including strategic, tactical weapon and "command and control" systems.

RAND's initial research foundation included operations research (the systematic study of military operations, such as bombing raids), systems engineering (the management of the design and development of technological systems), systems analysis (the comparison of systems that offered alternative solutions to problems), and system dynamics (the development of comparative system models used in policy making). Initially developed during the war, the new systems approaches provided a holistic vision of the interconnections between subparts of a system and their interfaces, as well as the understanding that a system included mechanical, electrical, and organizational components (e.g., a combination of missile technology and human operators).[15] As for research methods, David Hounshell argues that RAND's "brand of systems analysis, and its potent mix of mathematicians, logicians, economists, political scientists, and engineers helped to foster a major quantitative

16 David A. Hounshell, "The Medium Is
    the Message, or How Context Matters:
    The RAND Corporation Builds an
    Economics of Innovation, 1946–1962,"
    in Hughes and Hughes, *Systems,
    Experts, and Computers,* 255–310.

17 Crowther-Heyck, "Patrons of the
    Revolution," 426.

18 David A. Hounshell, "The Cold War,
    Rand and the Generation of Knowledge,
    1946–1962," *Historical Studies in the
    Physical and Biological Sciences* 27
    (March 1997): 261.

19 Sent, "Herbert A. Simon as a Cyborg
    Scientist," 383. Hounsell also argues
    that Simon's methods and approaches
    were shaped by the Cold War context, in
    Hounshell, "The Cold War, Rand and the
    Generation of Knowledge, 1946–1962."

20 Sent, "Herbert A. Simon as a Cyborg
    Scientist," 381. This militarized model
    was challenged from various perspec-
    tives, although the best known, centered
    on the body and its experiences, is
    Hubert Dreyfus, *What Computers
    Can't Do: A Critique of Artificial Reason*
    (Evanston, NY: Harper & Row, 1972).

21 Hounshell, "The Cold War, Rand and the
    Generation of Knowledge, 1946–1962,"
    244. See also Paul N. Edwards, *The
    Closed World: Computers and the Politics
    of Discourse in Cold War America*
    (Cambridge, MA: MIT Press, 1997).

22 Alex Abella, *Soldiers of Reason: The
    RAND Corporation and the Rise of the
    American Empire* (Orlando, FL: Harcourt,
    2008): 63.

revolution in the social sciences in the United States."[16] This revolu-
tion was founded on a popular perception of the natural sciences'
theoretical (and *financial*) success and the widespread conviction
that scientists, "whatever their field, were people who constructed
formal theoretical models and then tested them in controlled exper-
imental situations, preferably with sophisticated equipment."[17]

Simon was a RAND consultant from 1951 until 1976, and his
work on problem solving and digital computing with collaborator
Allen Newell was seminal in developing the new field of artificial
intelligence. Wedded to the idea that human intelligence could be
formally described by logical rules, Simon and his colleagues
worked on simulating human information-processing capabilities
on a digital computer at RAND's Systems Research Laboratory.
Simon and Newell's research evolved from chess-playing computer
programs in the 1950s to the 1960 General Problem Solver
(designed with J. C. Shaw), "which captured in computer language
their ideas about 'means–ends analysis' as a heuristic of human
problem solving."[18] The military ideal was ultimately mechanizing
control of inventory and production schedules, as well as weap-
onry, such as guided missiles, anti-aircraft guns, and torpedoes, all
of which required increasingly sophisticated decision making.

While at RAND in the 1950s, Simon's research focus and
methods shifted significantly from his earlier focus on decision
making in organizations to problem solving specifically "in
response to the concrete conditions of the Cold War and the practi-
cal goals of the military."[19] For the military, Simon and Newell's
work on artificial intelligence was appealing because it promised
more reliable outcomes than human intelligence: "Artificial intelli-
gence promised to allow the military to automate problem solving
in strategic situations…. In particular, simulating the mind as a
closed system subject to technical manipulation enabled the mili-
tary to integrate humans into their command and control sys-
tems."[20] In this artificial intelligence model, human intelligence was
understood as a critical processing component or decision-maker
within a complex system. RAND intellectuals "sought to build a
'science of warfare,' whereby the overall performance of the Air
Force could be optimized," both by prioritizing technological
approaches and by emphasizing "absolute" solutions to complex
problems.[21] Although RAND's attempt to change military planning
"from an intuitive process into a more rigorous science" did not
necessarily work in practice for the Air Force, "the rationality of
systems analysis was a powerful weapon it [the Air Force] could
use in policy debates to procure bigger budgets."[22]

The critique of the long-dominant Rational Economic Man
model, which assumed that man as a decision-maker is capable of
infinite information processing power, represented Simon's contri-
bution to economics, and in that critique, he was indebted to this
1950s problem-solving research. His later Nobel Prize was awarded

"for his pioneering research into the decision-making process within economic organizations,"[23] stemming from both *Administrative Behavior* and his 1950s articles, such as "A Behavioral Model of Rational Choice," in which he first challenged the Rational Economic Man model.[24] To counter the model, Simon argued that humans do not have the cognitive ability to recognize all possible alternatives and to calculate optimum solutions, so he proposed the ideas of "bounded rationality" and a "Satisficing Man" who makes satisfactory (rather than optimal) choices. Put simply, "the capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the real world."[25] Simon's "bounded rationality" thus described decision makers' limited computational capacities.

In the militarized model of problem solving, the limitations of human processing power could be augmented by the promise of computers with potentially infinite processing power. Despite the turn toward computer processing power, the Satisficing Male at the top of the military or management pyramid still retained the ultimate power—that of determining goals and framing choices.

From Cooking to Coding: Simon Commandeers Design
Simon's "science of design," outlined in his 1968 lecture, "The Science of Design: Creating the Artificial" and subsequently published in *The Sciences of the Artificial,* was a logical extension of his earlier research. One of three lectures in his MIT Karl Taylor Compton lecture series, "The Science of Design" was aimed primarily at an engineering audience and was described by Simon as "a prescription (a design!) for a curriculum in design."[26] Simon had some experience teaching engineering and architectural students at Illinois Institute of Technology in the 1940s and came to believe that, as with other professions, "engineering education needed less vocationalism and more science."[27] In his autobiography, Simon recalled that the architecture students were followers of Mies van der Rohe and Ludwig Hilbersheimer (a fellow Bauhaus alumni who taught city planning): "In this setting I felt less like a teacher than a missionary—one preaching not to tolerant pagans but to true believers of another faith..."[28] In 1968, the Compton lectures represented a missionary opportunity for Simon to commandeer the design professions into his ever-expanding problem-solving vision.

At its heart, "The Science of Design" was a call for pedagogical reform. "In terms of the prevailing norms," Simon argued, "academic respectability calls for subject matter that is intellectually tough, analytic, formalizable, and teachable. In the past, much, if not most, of what we knew about design and about the artificial sciences was intellectually soft, intuitive, informal, and cookbooky."[29] Not surprisingly, Simon proceeded to argue that design education suffers from a failure to engage with "the logic of optimization

23 "The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 1978," www.nobelprize.org/nobel_prizes/economics/laureates/1978/ (accessed April 28, 2014).

24 Herbert A. Simon, "A Behavioral Model of Rational Choice," *Quarterly Journal of Economics,* 69 (February 1955): 99–118.

25 Herbert A. Simon, *Models of Man: Social and Rational. Mathematical Essays on Rational Behavior in a Social Setting* (NY: Wiley, 1957): 198.

26 Simon, *Models of My Life,* 258–59.

27 Ibid., 257.

28 Ibid., 98.

29 Simon, *The Sciences of the Artificial,* 135.

methods" (here Simon cites his RAND colleagues, such as von Neumann and Arrow), which can be formalized into "a standard mathematical problem."[30] Simon's "science of design" thus frames design as a logical search for satisfactory criteria that fulfill a specific goal—and, of course, Simon and Newell's General Problem Solver (GPS) is proposed as ideal for searching through "a (possibly large) environment in order to discover and assemble sequences of actions that will lead it from a given situation to a desired situation."[31] Once design is reduced to problem solving, designers can augment their limited computational capacities by using computer programs to find the optimal solution.

For Simon, artificial intelligence had already started to revolutionize design. The issues in *The Sciences of the Artificial* were on Simon's radar at least a decade before, when he offered engineering as an example of a field already using computer programs modeled on human decision-making processes to "design without human intervention."[32] This technology-driven revolution promised also to change design education.

> Programs were designing electrical motors, generators, and transformers as early as 1956 and, by 1961, selecting investment portfolios. Such computer programs destroyed the mystery of intuition and synthesis, for their processes were completely open to examination. We could now understand, in whatever rigorous detail pleased us, just what a design process was. Understanding it, we could teach it, at the same level of rigor that we taught analysis.[33]

Artificial intelligence could thus elevate design to a scientific, research-based practice and provide an "intellectually tough, analytic, formalizable, and teachable" pedagogical foundation.

Simon's "science of design" is ultimately derived from his broader research aim over the previous two decades: developing an objective, value-neutral, quantifiable and mathematical field of research centered on problem solving. But more narrowly within an engineering educational context, for Simon, "design theory is aimed at broadening the capabilities of computers to aid design, drawing upon the tools of artificial intelligence and operations research."[34] In an essay on economics also included in *The Sciences of the Artificial,* Simon tellingly writes, "[o]perations research and artificial intelligence have enhanced the procedural rationality of economic actors, helping them to make better decisions."[35] This paternal attitude toward decision-makers—an attitude that can be traced back to *Administrative Behavior*—is crucial in establishing an important position for professional problem-solvers and their technological aids. For Simon's broader research agenda, not only are all kinds of professional (and many non-professional) activities essentially problem solving, but in an even more ambitious proposal, he argues that "scientific discovery is a form

30 Ibid., 116, 117. Worth noting here is that in the preface to the second edition of the book, Simon also specifically acknowledges the aid of a grant by the Advanced Research Projects Agency of the Office of the Secretary of Defense in developing his research in the chapters on design. Simon, *The Sciences of the Artificial,* xiv.

31 Ibid., 122–23.

32 Herbert A. Simon, "Theories of Decision-Making in Economics and Behavioral Science," *The American Economic Review* 49, no. 3 (June 1959): 276.

33 Simon, *Models of My Life,* 258.

34 Simon, *The Sciences of the Artificial,* 114.

35 Simon, "Economic Rationality: Adaptive Artifice," in Simon, *The Sciences of the Artificial,* 49.

36 Herbert A. Simon, "Scientific Discovery and the Psychology of Problem Solving," in Robert Garland Colodny, ed., *Mind and Cosmos: Essays in Contemporary Science and Philosophy* (Pittsburg: Pittsburg University Press, 1966). Simon repeats this point in a later essay, "The Scientist as Problem Solver," in *Complex Information Processing: The Impact of Herbert Simon,* Herbert A. Simon, David Klahr and Kenneth Kotovsky, eds. (Hillsdale, NJ: Erlbaum Associates, 1989): 375.

37 In a special issue of *Stanford Humanities Review* titled, "Bridging the Gap: Where Cognitive Science Meets Literary Criticism," Simon's paper does not engage with existing literary theory, except to dismiss it, and states that cognitive science can provide a new foundation. His monolithic vision of cognitive science is presented as a unified paradigm able to read poetry, for example, as a computer program. See Herbert Simon, "Literary Criticism: A Cognitive Approach," *Stanford Humanities Review* 4, no. 1 (Spring 1995): 1–26.

38 Simon, *The Sciences of the Artificial*, 135.

39 Herbert A. Simon, "The Structure of Ill-Structured Problems," in *Developments in Design Methodology*, Nigel Cross, ed. (Chichester: John Wiley and Sons, 1984), 145–66.

40 See Joel Isaac, "Tangled Loops: Theory, History, and the Human Sciences in Modern America," *Modern Intellectual History* 6, no. 2 (August 2009): 397–424.

41 Simon, *The Sciences of the Artificial,* 132.

of problem solving."[36] Late in his career, Simon even proposed unifying the disparate strands of literary theory through a cognitive science approach; literary criticism, he argued, was actually problem solving.[37]

If design, as Simon asserts, is ultimately a problem-solving activity, the "cookbooky" design pedagogy is unnecessary because computer programs can best solve problems. Indeed, Simon argues that "a considerable number of examples of actual design processes … in the form of running computer programs: optimizing algorithms, search procedures, and special-purpose programs for designing motors, balancing assembly lines" already exist and that "[t]here is no question, since these programs exist, of the design process hiding behind the cloak of 'judgment' or 'experience.'"[38] Derived from his earlier problem-solving research, Simon's design process operates within a closed, abstract system that is controlled and manipulated by a professional problem-solver and free from human judgment and experience. This model requires defining all aspects of the design process in terms of quantifiable, codifiable information and the designer as a type of expert computer coder. In an oft-cited 1973 paper that might have complicated this model, "The Structure of Ill-Structured Problems," Simon suggests some design problems may be "ill-structured" and not immediately solvable. However, he proceeds to argue that although the General Problem Solver is not suitable for a complex architectural design project that is "ill-structured," the whole can be broken down into "well-structured" sub-problems solvable by the program.[39]

For design research and education, Simon's "science of design"—with its focus on problem solving—remains appealing as an opposing model to a "crafts"-oriented image of the designer. Freed from the system of master artisans and apprentices derived from the Bauhaus (and earlier manifestations), both design research and education, following Simon's "scientific" lead, could legitimately enter the academic research system of the post-war university. This shift from studio practice to laboratory research entails a new subculture of scientific practices—training regimes, conceptual schemes embodied in research practices, and disciplinary training—to fashion the new designer (ironically modelled on a new apprenticeship system under an expert research scientist).[40] Inherent in this shift is a negation of problem solving as a creative process (creativity is relegated to the realm of the craftsperson/artist); for Simon, "solving a problem simply means representing it so as to make the solution transparent."[41] With its rigor and appeal to universality, Simon's logic of optimization promised knowledge that could be clearly and efficiently communicated, data that was free from the subjectivity of intuition, experience, and judgment. For design researchers, the "science of design" could potentially become "design as science."

The "Science of Design" in the 1960s

For later design researchers, Simon's "science of design" was aligned with the roughly contemporaneous Design Methods movement—particularly the latter's foundations in systems analysis, quantitative methods, and use of computers to aid the design process. From the 1950s, based at Germany's Hochschule für Gestaltung (HfG Ulm), Horst Rittel began applying ideas from cybernetics and operational research to design before moving to Berkeley in 1963 to help found the Design Methods Group and journal. In England, L. Bruce Archer's establishment of the Design Research Unit, at London's Royal College of Art in 1964, followed by a series of conferences and the foundation of the Design Research Society in 1966, were further attempts to apply scientific methods to design. Christopher Alexander's paper, "The Determination of Components for an Indian Village," delivered at the Conference on Systematic and Intuitive Methods in Engineering, Industrial Design, Architecture and Communications in 1962, serves as a good example of this early design research. In it, Alexander describes his use of mathematical methods and an IBM 7090 computer to design an Indian village for 600 people. Each specific need of the villagers—from religious rituals to social divisions, family structures, leisure, agriculture, animal husbandry, employment, water, transportation, education, health, economics, and relation to local and national developments—was given a number. As numerical values, the villager's needs were then connected as a set of interactions—"a complete structural description of the functional environment which contains the village and calls it into being. The beauty of this description is that we can now give it a mathematical interpretation, compatible with the real world facts, though nonetheless artificial...."[42]

However, initial attempts by designers, engineers, and architects, such as Alexander to establish scientific design methods in the 1960s were largely abandoned by the time of Simon's lectures, and designers associated with the Design Methods movement had already noted the limitations of mathematical logic in solving design problems.[43] Although Alexander is still quoted today as an advocate of design as a systematic, problem-solving activity, by 1984, he had already "recanted" in a famous interview, arguing that while computers have helped solve some mundane problems, "[m]ost of the difficulties of design are not of the computable sort."[44] Simon's *Sciences of the Artificial,* in both its first and subsequent editions, ignores the Design Methods movement and early design research such as Alexander's, which had already tried and abandoned his rigorous problem-solving approach. In a paper roughly contemporaneous with the publication of *The Sciences of the Artificial*, Rittel and Melvin Weber proposed an alternative model of the design process based on "wicked" problems. Contrasting scientists' problems as "tame," planning or social problems are

42 Christopher Alexander, "The Determination of Components for an Indian Village" in *Conference on Design Methods,* John Christopher Jones and D. G. Thornley, eds. (New York: Macmillan, 1963), 99–100.

43 Bruce Archer, for example, made this point in "Systematic Method for Designers" in *Developments in Design Methodology,* 57–82. Archer's essay was originally published in 1965.

44 Horst Rittel, interview by Donald P. Grant and Jean-Pierre Protzen, "Second Generation Design Methods," in *Developments in Design Methodology*, 312.

45 Horst Rittel and Melvin Weber, "Dilemmas in a General Theory of Planning," in *Panel on Policy Sciences, American Association for the Advancement of Science* 4 (1969): 160. Richard Buchanan, in his reflection on this issue, argues that a general "science of design" is impossible given that "design is fundamentally concerned with the particular, and there is no science of the particular." Richard Buchanan, "Wicked Problems in Design Thinking," *Design Issues* 8, no. 2 (Spring 1992): 17.

46 Rittel, "Second Generation Design Methods," 320.

47 Ibid., 326.

48 Frank Fischer, *Technocracy and the Politics of Expertise* (Newbury Park, CA: Sage Publications, 1990), 288.

49 Tomás Maldonado, *Design, Nature and Revolution* (New York: Harper and Row, 1970), 21–26.

50 Victor Margolin, "The Two Herberts," in *The Politics of the Artificial: Essays on Design and Design Studies* (Chicago: University of Chicago Press, 2002), 238. Another provocative contrast is with Noam Chomsky, a fellow revolutionary in the "cognitive revolution" in the social sciences, whose initial research was also substantially patronized by the U.S. military. However, by this time, Chomsky had taken a radically different path, epitomized by his anti-Vietnam War essay, "The Responsibility of Intellectuals," *The New York Review of Books* 8, no. 3 (February 23, 1967), www.nybooks.com/articles/archives/1967/feb/23/a-special-supplement-the-responsibility-of-intelle/ (accessed June 23, 2014).

51 George A. Miller, "Scientists of the Artificial", in *Complex Information Processing: The Impact of Herbert Simon,* 145.

52 Herbert A. Simon, "Motivational and Emotional Controls of Cognition," *Psychological Review* 74 (January 1967): 29–39; Herbert A. Simon and Allen Newell, *Human Problem Solving* (Englewood Cliffs, NJ: Prentice-Hall, 1972).

"wicked," they argued, and "rely upon elusive political judgment for resolution."[45] Contrary to the logic of Simon's military systems approach, no consistent, universal process can be followed, and problems are ultimately *resolved* rather than solved.

Acknowledging the social foundations of any design process, Rittel later called for "the understanding of designing as an argumentative process"[46]—one in which judgment is crucial. Contrary to the assumed neutrality and objectivity of Simon's problem solving, Rittel argued that all types of "planning are necessarily political, and not merely technical."[47] That is, the designer as problem solver in Rittel's model acknowledges the social and political agency of various stakeholders involved in the process. In contrast, Simon's "science of design" is founded on a technocratic model of problem solving. "For Simon," argues Frank Fischer, "the key to design lies in translating substantive decisions about goals and values into technical decisions about efficiency."[48] Rooted in *Administrative Behavior* and his subsequent military and organizational research, Simon's technocratic vision of design comprises a hierarchical chain of technical decisions directed by management at the top. Hiding behind a cloak of logical "optimization methods," Simon's "science of design" represented a potentially more efficient means of social and political control.

This point was not lost on Tomás Maldonado, who, in the context of the social and political unrest of the late 1960s, situated the "systems designers," or the "New Utopians" who proclaimed the supposed "ideological neutrality" of their models, firmly within the repressive political establishment.[49] More recently, Victor Margolin also situates Simon's "science of design" within the context of a 1960s counter-culture in which intellectuals such as Herbert Marcuse were beginning to question America's military–industrial complex.[50] Both Maldonado's and Marcuse's critique of "technological rationality," expose Simon's model of design as problem solving, based on the assumption that the mind is a disembodied information processor unaffected by particular cultural or historical discourses, as anything but value-neutral. Freed of situated bodies, Simon's "science of design" failed to engage with designing as a fundamentally social, political, cultural, and embodied activity.

Interestingly, outside the design research world, an entirely different perspective on Simon's "science of design" emerged—one in which *The Sciences of the Artificial* was received quite differently. George A. Miller, for example, described the book as another chapter in Simon's "pioneering contributions to cognitive psychology" and a visionary account of the field of "artificial intelligence."[51] Falling between Simon's 1960s papers, including "Motivational and Emotional Controls of Cognition," and the monograph *Human Problem Solving,* co-authored by Allen Newell, this perspective makes sense.[52] Professional design, engineering, and architecture do

not appear in Simon's later collections of papers (such as *Models of Thought)* and receive only fleeting interest after *The Sciences of the Artificial.*[53] In the context of his complete oeuvre, Simon's "science of design" can be seen as a brief engagement with engineering educational reform on the one hand and an extension of his problem-solving research and grand unification project for the social sciences on the other.[54]

Simon's Legacy in Design Research
Simon remains a venerated figure in design research circles, although the influence of *The Sciences of the Artificial* appears to be dissipating. In 2006, Kees Dorst argued that Simon's "conceptual framework," based on rational problem solving, "is still a dominant paradigm in the field."[55] In addition, a 2010 literature review found that Simon's *Sciences of the Artificial* is still a dominant citation across the research fields of information systems, management, design, and engineering.[56] Although Rittel and Weber's "wicked problems" presented an alternative and popular characterization of design as a social and political problem-solving activity, other alternatives have emerged since. Simon's "rational problem solving" model of the design process, for example, is often juxtaposed with Donald Schön's "reflection-in-practice" (as outlined in *The Reflective Practitioner),* a model that allows for both professional expertise and intuition.[57] Judgment, another characteristic of design practice expelled in Simon's "science of design," has been recently rehabilitated as a sophisticated and complex (yet still subjective and elusive) practice by Harold Nelson and Erik Stolterman as "design judgment." Including aesthetic and ethical considerations, they argue that design judgment is "a full and equal partner in any intellectual pursuit in design, on par with rational decision making."[58] In an ironic twist, even as digital technologies have become ever more ubiquitous since Simon's original lectures, the interest in the roles of intuition, experience, and judgment in design practice has increased rather than declined.

However, the appeal of Simon's rigorous "science of design" was part of a broader social scientific project "oriented more to the principles of prediction and control of behavior rather than to the values of human dignity, critical reflection, and democratic participation."[59] This promise of greater control has proven popular in recent characterizations of design thinking closely aligned to management. The logic of optimization promises greater predictability and profit while rigorously stripping judgment, intuition, and experience from systems and service design. Here, Simon's "science of design" is remarkably similar to what sociologist George Ritzer characterized as "McDonaldization"—a model that "emphasizes *efficiency, predictability, calculability, substitution of non-human for human technology, and control of uncertainty.*"[60] Not coincidentally, in his introduction to *The Design of Business: Why Design*

53 In the much later collection, *Models of Thought*, Simon briefly returns to engineering.

54 Simon's grand synthesis of psychology, artificial intelligence, mathematics, logic, and computing would later be gathered under the banner of cognitive science. See, for example, the early collection of essays edited by future design theorist Donald Norman: D. A. Norman, ed., *Perspectives on Cognitive Science* (Norwood, NJ: Ablex Publishing Company, 1981).

55 Kees Dorst, "Design Problems and Design Paradoxes," *Design Issues* 22, no. 3 (Summer 2006): 4.

56 Kalle Piirainen, Rafael A. Gonzalez, and Gwendolyn Kolfschoten, "Quo Vadis, Design Science? – A Survey of Literature," *Global Perspectives on Design Science Research* (Berlin: Springer, 2010), 93–108.

57 Kees Dorst and Judith Dijkhuis, "Comparing Paradigms for Describing Design Activity," *Design Studies* 16, no. 2 (April 1995): 261–74; and Jude Chua Soo Meng, "Donald Schön, Herbert Simon and The Sciences of the Artificial," *Design Studies* 30, no. 1 (January 2009): 60–8.

58 Harold Nelson and Erik Stoltenberg, *The Design Way: Intentional Change in an Unpredictable World,* 2nd ed. (Cambridge, MA: The MIT Press, 2012), 157.

59 Fischer, *Technocracy and the Politics of Expertise,* 345.

60 George Ritzer, "The 'McDonaldization' of Society," *Journal of American Culture,* 6, no. 2 (Summer 1983): 100.

Thinking Is the Next Competitive Advantage, Roger Martin describes Ray Kroc's changes to the McDonald brothers' original fast food service system:

> Kroc saw that the Speedee Service System, innovative as it was, left too much to chance and judgment. He refined it meticulously, pursuing a vision of a perfectly standardized operation. He simplified the McDonald's system down to an exact science, with a rigid set of rules that spelled out *exactly* how long to cook a hamburger, *exactly* how to hire people, *exactly* how to choose locations, *exactly* how to manage stores, and *exactly* how to franchise them.... In every phase of McDonald's operations, judgment was removed, possibilities were removed, and variety was removed. Kroc relentlessly stripped away uncertainty, ambiguity, and judgment from the processes that emerged from the McDonald brothers' original insight.[61]

Martin's glowing assessment of Kroc's method as an introduction to "design thinking" suggests the continuity and ongoing appeal of Simon's "logic of optimization" in a contemporary business context as "innovation."

To be fair, even within what was a dehumanizing approach, Simon left a small opening in his original "Science of Design" paper for social involvement and creativity. "Perhaps we should think of city planning," he wrote, "as a valuable creative activity in which many members of a community can have the opportunity of participating—if we have the wits to organize the process that way."[62] This alternate vision of a potentially participatory design process was further developed in Simon's later "Social Planning: Designing the Evolving Artifact," a lecture delivered in 1980 and published in the second edition of *The Sciences of the Artificial.* While Simon evidently believed computer programs could handle engineering, industrial design, or architectural problems, he envisaged social planning as different. Extending his earlier management research, Simon acknowledged the possibility of "designing without final goals" because, in the dynamic social realm, changing situations over time create new goals. Simon's social planning ideally aimed "to leave the next generation of decision makers with a better body of knowledge and a greater capacity for experience. The aim here is to enable them not just to evaluate alternatives better but especially to experience the world in more and richer ways."[63] Unlike the engineering designers and architects of "The Science of Design," social planners require both judgment and experience because final goals are ultimately limited by the future's unknowability.

Reflecting on this social dimension to Simon's revised "science of design," John Carroll, in "Social Planning: Designing the Evolving Artifact," generously suggested that Simon may have

61   Roger Martin, *The Design of Business: Why Design Thinking Is the Next Competitive Advantage* (Boston: Harvard Business Press, 2009).

62   Simon, *The Sciences of the Artificial,* 130.

63   Ibid., 163–64.

64 John M. Carroll, "Dimensions of Partici-
    pation in Simon's Design," *Design Issues*
    22, no. 2 (Spring 2006): 8.

65 Ibid., 17.

66 Most recently, Hatchuel and colleagues
    have argued that "an ontology of design
    is grounded on an ontology of expan-
    sion." Armand Hatchuel, Benoit Weil,
    and Pascal Le Masson, "Towards an
    Ontology of Design: Lessons from C-K
    Design Theory and Forcing," *Research
    Design Engineering* 24, no. 2 (April 2013):
    160.

67 Armand Hatchuel, "Towards Design
    Theory and Expandable Rationality: The
    Unfinished Program of Herbert Simon,"
    Journal of Management and Governance
    5, no. 3/4 (September 2002): 6.

68 Ibid., 9.

69 Rabah Bousbaci, "'Models of Man' in
    Design Thinking: The 'Bounded Rational-
    ity' Episode," *Design Issues* 24, no. 4
    (Autumn 2008): 38–52.

70 See Bousbaci, "'Models of Man' in
    Design Thinking: The 'Bounded Rational-
    ity' Episode," 50. Reflecting on Simon's
    work, Miller writes, "[i]n decision science
    there is no audience." Carolyn R. Miller,
    "The Rhetoric of Decision Science, or
    Herbert A. Simon Says" in Herbert W.
    Simons, ed., *The Rhetorical Turn: Inven-
    tion and Persuasion in the Conduct of
    Inquiry* (Chicago and London: University
    of Chicago Press, 1990), 176.

71 Bousbaci, "'Models of Man' in Design
    Thinking," 50.

72 Tony Fry, *Design Futuring: Sustainability,
    Ethics and New Practice* (Oxford: Berg,
    2009), 118; Clive Dilnot, "Ethics in
    Design: 10 Questions," Hazel Clark and
    David Brody, eds., *Design Studies: A
    Reader* (Oxford: Berg, 2009): 180–90.

been sympathetic to the ideals of participatory design as it devel-
oped in the 1970s. However, even here, Carroll identified "Simon's
tendency to see relationships in terms of the underlying logic, but
not the social dynamics."[64] Carroll rightly sees the issue of commu-
nication as crucial to design processes, arguing that "[c]ommunicat-
ing directly with actors in order to understand their experience of
their environments and their needs for new designs is not simple."[65]
The active involvement of clients and users in the design process is
certainly absent from Simon's earlier "science of design."

More recently, Armand Hatchuel has tried to develop
Simon's "bounded rationality" further into an "expandable ratio-
nality" that might involve greater social interaction.[66] He argues
that Simon's attempt to develop a formal design theory was unfin-
ished, noting "Simon's limited interest for the construction of social
interaction, which is a key resource of design processes."[67] High-
lighting the limitations of Simon's problem-solving model,
Hatchuel argues that "human agents are limited decision makers
but 'good' natural designers (including social interaction as a
design area)."[68]

The limits of Simon's "science of design" are also high-
lighted in Rabah Bousbaci's overview of Simon's "bounded ratio-
nality."[69] Among the later critics of Simon, Bousbaci first examines
Carolyn R. Miller's "rhetorical" perspective, in which she argues
that problems of action are "essentially contestable."[70] Like Rittel's,
Miller's perspective frames design as a form of interaction that
always implies some kind of negotiation between people involved
in the process. Then, adding to this essentially political dimension
of design, Bousbaci concludes that "what really bounds rationality
in human action is nothing more than all the other parts which
comprise [sic] the human existence as a whole: poetics, rhetoric,
hermeneutics, and ethics; because, when humans act, they act as
whole humans."[71] The issue of ethics is particularly critical here,
and the interest in user-centered design, participatory design, and
other variations on co-design since Simon's *Sciences of the Artificial*
confirms a shift away from his technocratic designer ideal to an
acknowledgement of design's ethical foundation. Design theorists,
such as Clive Dilnot and Tony Fry, have recently extended this ethi-
cal foundation to include not only relations between designers, cli-
ents, and stakeholders, but also an understanding of sustainability
as "embodied in practices and things."[72]

What is inescapable in all of these critiques of Simon's "sci-
ence of design" is the issue that remains when devising "courses of
action aimed at changing existing situations into preferred ones":
Who determines the "courses of action" and whose "preferred situ-
ations" are we to design?