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## **SIMON: DESIGN AS A PROBLEM-SOLVING ACTIVITY**

**Willemien Visser**

### *Abstract*

In this paper, we present Simon's approach to design, as we have described it in *The Cognitive Artifacts of Designing* (2006): Simon considers the sciences of design as sciences in their own right. He sees them as distinct from natural science, which is traditionally considered as "the" "science". "Artificial" indeed refers to human-made as opposed to natural. For Simon, our modern world is much more an artificial, that is, a human-made, than a natural world. Together with various colleagues, Newell and Simon also used the approach to explore broader domains than the one analyzed in their famous Human Problem Solving (1972). They used it for their research into concept formation, verbal learning, and perception, but also administrative and organizational behavior, creativity and scientific discovery, and even music and emotion. It was Simon who applied to design the paradigm developed with Newell. In his analyses, he identified and elaborated various characteristics of this specific problem solving activity that have formed the basis of the approach adopted toward design by many researchers in cognitive psychology and ergonomics conducting research on design since the early 1980s.

### **Simon: Design as a Problem-Solving Activity**<sup>1</sup>

This first chapter presents Simon's approach to design.

#### **Simon's Framework for Design: *The Sciences of the Artificial***

Simon's bibliography comprises nearly 1,000 titles, among which are some 700 papers published in journals in domains ranging from public management to the axiomatization of physical theories (*Bibliography of Herbert A. Simon*). He published only some 10 papers directly concerned with design (Cagan, Kotovsky, & Simon, 2001; Kim, Javier-Lerch, & Simon, 1995; Simon, 1969/1996, 1971/1975, 1973/1984, 1977b, 1980, 1987/1995, 1997). The number amounts to some 20 if one also includes publications dealing mostly with organizational design, but that do not handle with cognitive aspects.

*The Sciences of the Artificial* (Simon, 1969/1996)<sup>2</sup> is, however, one of Simon's seminal works and one of the definitely fundamental references exploited in cognitive analyses of design. The "sciences of design" are the core of these "sciences of the artificial" (or "artificial sciences," e.g., engineering, computer science, medicine, business, architecture, painting, the human and social sciences). Even if only two chapters of the book are dedicated specifically to the nature of design, this is the central issue of the entire book. Together with the paper on "The Structure of Ill-Structured Problems" (1973/1984), these are Simon's central publications in his work on design. [...]

One may notice that "sciences of the artificial" may be a more appropriate appellation than "artificial sciences," which may also refer to the domains of artificial intelligence and artificial life [...].

*The Sciences of the Artificial* went into three, each time revised, editions. Its first, the 1969 edition, [...] introduced the chapter "The Science of Design: Creating the Artificial." [...] [The 1981 version] introduced a second chapter specifically on design, namely "Social Planning: Designing the Evolving Artifact." Taken together, the conclusions of the two design chapters constitute the main lines of a curriculum for design education formulated by Simon. In 1996, the third edition introduced a new chapter on complexity, "Alternative Views of Complexity." [...] In his analysis of Simon's work, Carroll (2006) [...] notices an evolution in the nature of the new chapters. The addition of the chapter "Social Planning: Designing the Evolving Artifact" translates for him Simon "considering design as a social activity in several different senses" (p. 5).

In the present chapter, the page numbers for quotations from *The Sciences of the Artificial* come from the third printing of the third edition of the book (Simon, 1969/1996).

From the first edition on, Simon considers the sciences of design as sciences in their own right. He sees them as distinct from natural science, which is traditionally considered as "the" "science." Yet, in a lecture given in 1987 (not included in *The Sciences of the Artificial*), Simon proposes to "compromise" on a perhaps less "pretentious" qualification, as he calls it, speaking of "the art and science of design" (Simon, 1987/1995, p. 245). As Simon writes in the chapter titled

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<sup>1</sup> This paper is entirely composed by quotes from our book *The cognitive artifacts of designing* (2006). Mahwah, NJ: Lawrence Erlbaum Associates

<sup>2</sup> The 1<sup>st</sup> edition of Simon's book (Simon, 1969) has been translated in French by Le Moigne in 1974 (Simon, 1969/1974) and exists now in a paperback version (Simon, 1996/2004).

"The Science of Design: Creating the Artificial" (in which engineering design is the reference), "historically and traditionally, it has been the task of the science disciplines to teach about natural things: How they are and how they work. It has been the task of engineering schools to teach about artificial things: How to make artifacts that have desired properties and how to design" (Simon, 1969/1996, p. 111). Natural science is concerned with the necessary, with how things are, whereas design is concerned with the contingent, with how things might be (Simon, 1969/1996, p. xii)—or *ought* to be.

Designers are "concerned with how things *ought* to be . . . in order to *attain goals* and to *function*" (Simon, 1969/1996, pp. 4-5). Simon's thesis is indeed that "certain phenomena are 'artificial' in a very specific sense: They are as they are only because of a system's being molded, by goals or purposes, to the environment in which it lives" (Simon, 1969/1996, p. xi). That is why symbol systems (or "information processing systems") are "almost the quintessential artifacts[:] Adaptivity to an environment is their whole *raison d'être*" (Simon, 1969/1996, p. 22). "Artificial" indeed refers to human-made as opposed to natural. For Simon, our modern world is much more an artificial, that is, a human-made, than a natural world.

### **SIMON'S ELABORATION OF AN SIP DESIGN THEORY<sup>3</sup>**

Two steps can be distinguished in Simon's elaboration of a cognitive design theory. The first one was taken together with Newell, to whom *Sciences of the Artificial* is being dedicated "in memory of a friendship." Jointly, the two researchers extended what has since been called the principles underlying the "symbolic information processing" approach to problem solving (Newell & Simon, 1972)—or abridged the "symbolic processing" (Greeno & Moore, 1993, pp. 57-58), "symbolic" (Vera & Simon, 1993, p. 10), or "information-processing" approach (Simon, 1978, p. 272), here abridged as the SIP approach. It is also frequently referred to—often by authors adopting a different approach—as the "rational problem-solving" (Dorst, 1997), "traditional," or "computational" view.

The SIP approach has been one of the main starting points of the "cognitivist" perspective in cognitive science. In the early years of cognitive psychology, many authors embraced this paradigm as the fundamental schema for their investigation of cognitive activities. For some 20 years, it has been *the* theoretical reference for the cognitive analysis, not only of problem solving (Miller, Galanter, & Pribram, 1960; Reitman, 1965), but also of other types of activities: Concept learning (Bruner, Goodnow, & Austin, 1956), and verbal understanding and memory (Anderson, 1976, 1983; Le Ny, 1979, 1989a, 1989b). Together with various colleagues, Newell and Simon also used the approach to explore broader domains than the one analyzed in their famous *Human Problem Solving* (1972). They used it for their research into concept formation, verbal learning, and perception, but also administrative and organizational behavior, creativity and scientific discovery, and even music and emotion (for references, see Newell & Simon, 1972, p. 791, Note 1).

It was Simon alone—namely without Newell—who, subsequently, applied this paradigm to design (Simon, 1969/1996, 1971/1975, 1973/1984, 1987/1995). In these analyses of design, Simon identified and elaborated various characteristics of this specific problem-solving activity that have formed, for some 10 to 15 years, *the basis* of the approach adopted toward design by many, if not most, researchers in cognitive psychology and cognitive ergonomics who have been conducting research on design since the early 1980s.

With one exception (Okada & Simon, 1997), as far as we know, Simon was only concerned with individually conducted problem solving. This does not mean that he was a researcher who especially underestimated the importance of collective problem solving. In the 1960s and 1970s, few psychologists dealt with collectively conducted activities, analyzed from a cognitive viewpoint—there was, of course, research in social psychology, but these studies did not deal with cognitive aspects of problem solving.

Notice that the general reference for problem solving, the SIP model, was presented in 1972 (Newell & Simon, 1972), whereas the first edition of *Sciences of the Artificial* had already been published in 1969.

### **SIMON'S ANALYTICAL APPROACH TO DESIGN**

Contrary to Simon's elaboration of a general theory of problem solving, which was based on experimental research, his work on design was analytical. With one or two exceptions (Kim et al., 1995), Simon indeed has not been involved in any empirical studies on design. This observation holds for "design" in a strict sense—such as Simon gave to the term. From the end of the 1950s on, Simon realized, in collaboration with various colleagues, a considerable body of research on scientific discovery, leading to two books (Langley, Simon, Bradshaw, & Zytkow, 1987; Simon, 1977a) and more than 40 papers (Cagan et al., 2001; Klahr & Simon, 2001; Kulkarni & Simon, 1988; Okada & Simon, 1997; Qin & Simon, 1990; Simon, 1977a, 1992a, 1992b, 2001). Even if in our view, scientific discovery is based on the same cognitive activities and operations (and, of course, cognitive processes) as implemented in design, Simon nearly establishes no link with design (see, however, Cagan et al., 2001 [...]).

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<sup>3</sup> "SIP" is the abbreviation for "symbolic information processing," the approach adopted by Simon (1969/1996) for analyzing design. This approach was originally developed by Newell and Simon for problem solving.

## RECEPTION OF SIMON'S DESIGN FRAMEWORK

In 1964, Reitman adopted a representation for problem solving that could be formalized using the IPL-V information-processing language elaborated by Newell, Shaw, Simon, and other colleagues in the 1960s<sup>4</sup>. Reitman applied this problem-solving schema to the solving of what he qualified as "ill-defined" problems [...]<sup>5</sup>.

The architect Eastman (1969) was one of the first researchers to adopt the SIP framework for the analysis of design. He did so in what was at the time a particularly original study in the domain of empirical design research. He analyzed a protocol collected in a laboratory study concerning an architectural problem. Even if the problem was rather simple, his protocol study constitutes a reference in the domains of empirical studies of design, on the one hand, and of ill-defined problems, on the other.

There are also many authors who globally adopt Simon's framework, but propose more or less profound complements or modifications (Akin, 1986a, 1986b; Baykan, 1996; Goel, 1994; Goel & Pirolli, 1992; Hamel, 1995; Lebahar, 1983). Simon's ideas continue to be "a dominant force within the field," as noted by Roozenburg and Dorst (1999), who illustrate their claim by an analysis of the papers presented at the two first Design Thinking Research Symposia (DTRS) organized in Delft in 1992 and 1994 (Cross, Christiaans, & Dorst, 1996; Cross, Dorst, & Roozenburg, 1992). They observe that "Simon was referred to more than anyone else: 31 direct references and goodness knows how many indirect ones in 32 papers" (p. 34, Note 3).

An explanatory hypothesis, which we have detailed in an analysis of 15 empirical design studies (Visser, 1994), is that the adoption by cognitive design researchers of rather strict SIP positions may be due to their data collection having been carried out in a laboratory or otherwise restricted context. An example is Goel (1995, p. 114) who observes and describes a quite orderly organization of the design process in different, consecutive stages. It should be noticed, however, that he has developed an innovative view with respect to a fundamental issue in cognitive modeling, that is, the status of representations. He did so around the notion of "sketch" [...].

From the end of the 1970s on, authors from various disciplines—psychology, sociology, ethnology, and anthropology—have been proposing other paradigms to the cognitive study of design (Bucciarelli, 1984, 1988; Rittel, 1972/1984, 1973/1984; Schön, 1983, 1988, 1992).

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<sup>4</sup> IPL (information-processing language) was the first list-processing computer language.

<sup>5</sup> Adopting a slightly different position than that of Simon, we consider a "problem" to be "ill-defined" ("ill-structured" for Simon, 1973/1984) when the three components that one classically distinguishes in a problem—its initial state, its final state and the operators for moving from one to the other—are not defined in an explicit and exhaustive manner. For a design "problem", this means that, habitually, the specifications of the design project—its final state—specify the artifact at quite an abstract level, by its function and/or by certain constraints, while the initial state and the operations are almost always underspecified.

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