



Center for
***LifeLong
Learning
& Design***

University of Colorado at Boulder

**Wisdom is not the product of schooling
but the lifelong attempt to acquire it.
- Albert Einstein**

Design = The Sciences of the Artificial

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The Sciences of the Artificial

- **“The Sciences of the Artificial” — a book by Herbert Simon**
 - 1st edition: 1969
 - 2nd edition: 1981
 - 3rd edition: 1996
- **who is Herbert Simon:**
 - a founder of Artificial Intelligence
 - a Nobel Prize Winner in Economics
 - a major figure in Psychology and Cognitive Science

Boundaries for the Sciences of the Artificial

- artificial things are synthesized (though not always or usually with full forethought) by humans
- artificial things may imitate appearances in natural things while lacking, in one or more respects, the reality of the latter
- artificial things can be characterized in terms of functions, goals, adaptation and flexibility
- artificial things are often discussed, particularly when they are designed, in terms of imperatives as well as descriptives
- **Alan Kay (Scientific America, Sept 84, p 57)**
“molecular biology has the advantage of studying a system already put together and working; for the composer of software the computer is like a bottle of atoms waiting to be shaped by an architecture he must invent and then impress from the outside”

The Unifying Themes in Simon's Work

- **bounded rationality** = there are limits on a human as a decision maker and a problem solver (especially limits in cognitive processing) → these limits are important for the behavior of humans
- **satisficing** = accepting solutions which are “good enough”
 - *“The best is often the enemy of the good”*
 - the concept of *“satisficing”* separated Artificial Intelligence from Operations Research

Some Famous Quotes from Simon

- “What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate efficiently among the overabundance of information sources that might consume it.”
importance: contextualizing information (beyond current “push” technologies, making information relevant to the task at hand, critiquing,
- “The smartest people in the world do not generally look very intelligent when you give them a problem that is outside the domain of their vast experience.”
importance: domain-orientation, human problem-domain interaction
- definition of design = “Everyone designs who devise courses of action aimed at changing existing situations into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that prescribes remedies for a sick patient or the one that devises a new sales plan for a company or a social welfare policy for a state”

Some Systems Developed by Simon

- **systems**

- **Logic Theory Machine (LT)** → finding proofs of theorems in elementary symbolic logic
- **General Problem Solver (GPS)** → a program that simulates human thought (objects, operators, differences)
- **Bacon** → scientific discovery: to induce laws from data

→for more information see: Feigenbaum, E. A. & Feldman, J. (1963) Computers and Thought, McGraw-Hill Book Company, New York.

Some Concepts Developed by Simon

- **ill-defined problems**
- **informational efficiency:** two representations are informationally equivalent if all of the information in the one is also inferable from the other, and vice versa. Each could be constructed from the information in the other.
- **computational efficiency:** two representations are computationally equivalent if they are informationally equivalent and, in addition, any inference that can be drawn easily and quickly from the information given explicitly in the one can also be drawn easily and quickly from the information given explicitly in the other, and vice versa
- ***informational equivalence versus computational equivalence of representations*** → *“even if two representations contain exactly the same information, it may be far cheaper, computationally, to make some of this information explicit using one representation than using the other”*

Number Scrabble and Representations

- **number scrabble:**

- two person game
- numbers from 1 to 9
- players alternate and take one of the numbers
- the player who can add exactly three numbers in her/his possession to equal 15 will win

- **critical importance of representations in design:**

“Solving a problem simply means representing it so as to make the solution transparent”

Well-Defined versus Ill-Defined Problems

- **Well-Defined Problems:**
 - the essential conditions of the problem are stated
 - their solutions are the same for all problem solvers
 - examples: school problems, mutilated checker board, implementing given algorithms
- **Ill-Defined (or Wicked) Problems:** problem solvers take an active role what the problem is
 - fill gaps in the problem definition
 - jump into the problem
 - use information gained while trying to solve the problem
 - examples: architects, engineers, lawyers, legislators, software designers, writers, teachers,

Design Deals with Wicked or Ill-Defined Problems

Rittel in Cross "Developments in Design Methodology"

- there is no definitive formulation of a wicked problem. For any given tame problem, an exhaustive formulation can be stated containing all the information the problem-solver needs for understanding and solving the problem.
- they have no stopping rule. In tame problems, problem solvers know when they have done the job. Problem solvers terminate work on a wicked problem, not for reasons inherent in the 'logic' of the problem.
- solutions to wicked problems are not “true-or-false”, but “good-or-bad”
- every wicked problem is essentially unique
- the aim of design is not to find the truth, but to improve some characteristics of the world where people live

Examples for Large-Scale Design

- **going to the moon** → a “complex” problem along one dimension;
sources for success:
 - exceedingly cooperative environment
 - employing a single new organization
 - single, highly operational goal
- **the American Constitution:**
“the founding fathers did not postulate a new man to be produced by new institutions but accepted as one of their design constraints the psychological characteristics of men and women as they knew them, their selfishness as well as their common sense”
- **we need not so much a “correct” conceptualization as one that could be understood by everyone**
 - architects and software engineering: communication between clients, designers and users
 - “symmetry of ignorance” (Rittel): “there is nobody among the carriers of knowledge who has a guarantee that his knowledge is superior to any other person's knowledge”

The Shape of the Design: Hierarchy

The Problem of Modularity

- **claim:** to design a complex structure, one powerful technique is to discover viable ways of decomposing it into semi-independent components corresponding to its many functional parts. The design of each component can then be carried out with some degree of independence of the design of others, since each will affect the others largely through its function and independently of the details of the mechanisms that accomplish the function.
- **examples:**
 - functional programming
 - object-oriented programming
 - rule-based systems
 - nearly decomposable systems

Tempus and Hora

- watches of a 1000 parts — interruptions by phone calls
- Tempus: interruptions lead to restart from scratch
- Hora: subassemblies of ten (at each level) ---> 111 subassemblies
- *the evolution of complex forms from simple elements depends critically on the numbers and distribution of potential stable intermediate forms*

Desiderata

- to create system / a world which offer as many alternatives as possible to future decision makers, avoiding irreversible commitment that they cannot undo ---> adaptable, end-user modifiable systems
- allow people to design ---> the act of envisioning possibilities and elaborating them is itself a pleasurable and valuable experience
- to leave the next generation of decision makers with a better body of knowledge and a greater capacity for experience