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ABSTRACT

This paper address three questions: (1) What is the nature of design? (2) How do skilled designers function? and (3) Can a theory of design be constructed which will allow novice and expert instructional designers to perform their tasks more efficiently and effectively? It begins by presenting two general theories of design: Simon's conception of design as optimization, i.e., a process of heuristic problem solving; and Schon's conception of design as dialogue, i.e., a process of reflection-in-action or a dialogue with phenomena that can be seen as a kind of social process of negotiation. It is argued that, although the main philosophical basis of modern instructional design--the systems approach--has been closer to Simon's view than Schon's, support for the design-as-dialogue interpretation has been expressed by Banathy, and empirical studies of novice and expert designers have provided examples of both approaches. A review of 21 studies is presented in chart form, including the name(s) of the researcher(s) and the date of the study, the domain, and a summary of the findings/content of the report. A discussion of educational/instructional design reviews additional research, including Tyler's "rational means-ends" model of curriculum planning, Walker's summary of several curriculum development projects, Cain's "creative planning model," and studies of instructional design processes by Kerr and Nelson. It is concluded that prescriptive design methodologies must support real-world methods in order to be effective, and that tools for instructional designers should support their preferred methods. Seven recommendations by Guindor for designers in a computer environment conclude the paper, and an extended bibliography lists 127 items. (BBM)

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Introduction

Nobel Laureate, Herbert Simon (1981) addressed the nature of fields like computer science, engineering, and education by proposing a difference between the natural sciences and what he called "sciences of the artificial." The four qualities that separate the natural sciences from the artificial or design sciences are: 1) artificial things are synthesized by man, 2) they imitate appearances of natural things but lack the reality of them, 3) artificial things can be characterized in terms of functions, goals and adaptation, and 4) artificial things are usually discussed in terms of imperatives as well as descriptives.

Simon wrote that, *"...the proper study of mankind is the science of design...."* (1969/1981, p. 159) Simon conceived of design as encompassing all kinds of human activity which involve planning. *"Engineers are not the only professional designers. Everyone designs who devises 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. Design, so construed, is the core of all professional training; it is the principle mark that distinguishes the professions from the sciences. Schools of engineering, as well as schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design."* (1969/1981, p. 129)

Design is any purposeful making or doing that involves planning. Design encompasses most kinds of skilled behavior used in achieving goals under uncertain conditions. Teachers, administrators, politicians, doctors, engineers, lawyers and researchers are daily involved in design activities. Given the ubiquity of design-like situations it is surprising that so little is known about it.

The Problem.

What is the nature of design? How do skilled designers function? Can a theory of design be constructed which will allow novice and expert instructional designers to perform their tasks more efficiently and effectively? Although there are many opinions on these subjects, those many views can perhaps best be epitomized by two general theories of design.

1: Design as Optimization.

Simon conceived of design as an instance of problem-solving. Problem-solving involves moving the current situation progressively closer to the goal situation. A formal description of problem-solving involves representing the problem as a problem-space with initial, intermediate, and goal states. The solution to the problem involves searching for operators which will transform the initial state into the goal state. For ill-structured problems, heuristics rather than algorithms are required to achieve ends. A standard heuristic for the solving of difficult problems is means-ends analysis. Ends are defined and means to those ends are specified. If no means are apparent, the problem is decomposed into a hierarchy of sub-problems. This decomposition continues until means are discovered to solve the sub-problems. Thus, problem solving and therefore design, is a matter of finding the best description of the problem. In Simon's interpretation, a theory of design is equivalent to a formal representation of problem-solving heuristics.

2: Design as Dialogue

Donald Schön, a philosopher who has been involved with architects, has as a goal the development of an an epistemology of practice; that is, a characterization of the kinds of knowledge which a skilled designer/planner must possess. As a result of his observations of professional architects, he has proposed an alternative view of design. Schön (1988) has argued that the defining characteristics of design activities are *uncertainty*, *uniqueness* and *conflict*. Schön does not see design as heuristic problem-solving. On the contrary, design is a process of reflection-in-action; and designers take on the task of turning indeterminate situations into determinate ones (Schön, 1987).

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Design, in this view, is a dialogue with phenomena. It can be seen as a kind of social process of negotiation. The objects of a design world are like Seymour Papert's objects to think with. We make worlds (in Goodman's sense), Schön says, through a Gestalt-like process consisting of selective attention, grouping, boundary setting, and naming. By classifying we create **types**. Schön believes types are particulars that function in a general way. He asserts that the transaction between familiar type and unique design situation is a **metaphorical** process in which a designer both transforms a design situation and enriches the repertoire of types available to him for further design. Design, by this reading, has a hermeneutic quality. Problems do not have an objective existence, but rather are constructions created by designers as they grapple with uncertainty.

Implications

The main philosophical basis of modern instructional design has been the systems approach. The traditional interpretation of the systems approach has been much closer to Simon's view than Schön's. Thus instructional designers were trained in a means-ends analysis methodology and were expected to conform to this methodology in their professional life. Interestingly, Bela Banathy, an early advocate of the linear systems approach for instructional designers, has recently published a paper (Banathy, 1987) which aligns the systems approach more closely with the design-as-dialogue interpretation. He now sees design as holistic, interactive, spiralic, and dialectical. In spite of this change, the education of instructional designers still consists of exposure to hierarchical, top-down methods of problem decomposition. Additionally, empirical studies of novice and expert designers have indicated that in many cases, designers deviate from the hierarchical top-down type of design that Simon hypothesizes. Since both hierarchical and opportunistic approaches have both been observed in skilled designers, it may be that both Simon and Schön are, in a sense, correct, but they are describing different approaches used by people of differing abilities working on different kinds of problems.

Review of Literature

Empirical Studies of Design

There is a small, but growing, body of research on the activities of designers in action. This literature spans such areas as architecture, engineering, and computer science. The following table summarizes a portion of the published data on design outside of education.

Name & Date	Domain	Content
Adelson & Soloway (1984, 1985) in Guindon (1990)	Systems design	Three expert designers' work was systematic and balanced. Balanced means no part of the design was developed in significantly greater detail than other parts. Unbalanced design was followed only when a part was not familiar
Bucciarelli, L. L. (1988).	An ethnographic perspective on engineering design.	Studied design process within an engineering firm. Previous studies showed that a design team spent less than half of their time on legitimate design acts. Describes a discourse between three engineers and the artifact of design itself. Different aspects of an artifact are of interest to different persons. Differently schooled persons inhabit different "object worlds," each with its own symbols, metaphors, and models. Cites three cases of design discourse (specification, naming and decision making). Concludes: Values and beliefs do not derive from free choice; design change will not come by influencing young engineers. Ambiguity is always with us. Artifacts are not the design; they symbolize agreements. Knowledge is context-dependent but there will always be design moves that reach across boundaries.

Carroll & Rosson (1985)	General design	Examined empirical studies of designers in action and based on these studies they argue that the process is: (1) non-hierarchical, (2) neither strictly bottom-up nor top-down, (3) radically transformational, involving the development of partial and interim solutions which may ultimately play no role in the final design, and (4) intrinsically involving the discovery of new goals.
Cornforth (1976, in Lera, 1983)	Architectural design	Found subjects alternated between specification and search processes, contrary to standard methods. Designers develop a simple solution with a superficial plausibility and use that to develop a more detailed solution.
Curtis, B., Krasner, H., & Iscoe, N. (1988).	A field study of the software design process for large systems	Anecdotal report of the thinking of system designer on the design process. Software development is learning, negotiation, and communication process.
Darke (1979, in Lera, 1983)	Architectural design	Found that designers do not start with an explicit list of factors to be considered.
Downing, F. (1987).	Architecture	Studied architects working on a building project. Thematic, analogous and "charged" imagery creates a framework of thought. Prototypical solutions prestructure problems (design-by-precedent). The basic model of involves "conjecture-analysis." architects have an "image bank" of memorable solutions. Design is "seeing-as" (in Schon's terms).
Eastman (in Lera, 1983)	General design	Found a correspondence between representation used and constraints discovered. Instead of generating abstract attributes and relationships, subjects generated a design element and determined its qualities.
Foz (1972, in Lera, 1983)	Architectural design	Found designers use existing known examples to solve problems. Some manipulated 3-D models as if they were reality. Most skilled subject called on precedents, made many proposals, performed more tests, use more analogies deliberately, and was explicitly aware of his creative process. Whatever the designer is confident of being able to produce is put aside until it is needed. Designers deal with problems by consulting precedents.
Guindon, R, (1990)	Software design	Analysis of protocols of three software designers working on the Lift problem. Concludes that design process for expert designers is both opportunistic and top-down. Top-down is a special case when problem is well-structured. Makes recommendations for the design of environments that support opportunistic design.
Guindon, R., Curtis, B., & Krasner, H. (1987).	A model of cognitive processes in software design: An analysis of breakdowns in early design activities by individuals	Protocols of three experienced designers indicate three main sources of breakdowns: Lack of knowledge, cognitive limitations and combinations of those two factors. Designers exhibited huge individual differences in their design strategies and their design solutions. These finding could not be accounted for by prescriptive models.

Hykin (1972, in Lera, 1983)	Engineering design	Reports eleven case studies of engineers and concludes that it is impossible to isolate and identify simple design strategies. However he reported that exploration of alternatives led to a clearer understanding of the problem. Engineers expressed a need for a method of recording design decisions.
Jeffries, R., Turner, A. A., Polson, P. G., & Atwood, M. E. (1981).	The processes involved in designing software.	Studied four experienced software designers and five novices: Great variety of solutions both within and between levels. Novices lacked processes for solving subproblems and ways of representing knowledge effectively. Most experienced designer had many digressions. Some used "problem-solving-by-understanding."
Klein, G. A. (1987).	Various real-world design situations.	Reports several studies of designers dealing with difficult problems. Ill-defined problems require goal clarification and option development. Recognitional processes play a key role in design decision making as well as problem solving. Found little evidence of systematic use of decision analysis methods. Use of analogs lead to comparison-based prediction. Imagery is an important part of design. Research is used selectively and only to support preferences. Rapid prototyping is an attractive strategy for designers.
Lawson, B. (1980).	Architecture	Compared design strategies of final-year architectural students and science students at a comparable point in their education. Strategies were different but consistent. Scientists were problem-driven and sought to discover a rule. Architects were solution-driven and sought to learn about the problem from plausible solutions. In a second experiment with the same materials, high school and first year architecture students were tested. Both performed more poorly than the postgraduate students and neither group showed consistent patterns. Thus the consistent strategies of the architects were not a natural tendency.
Lee, T. Y., & Radcliffe, D. F. (1990).	Innate design abilities of first year engineering and industrial design students.	Two hundred twenty-six students studied by retrospective review. Experience improves design skills. Engineering and industrial design students exhibited clear differences of attitude, and this may be reflected in their choice of career. There appeared to be an "engineering way" of approaching design tasks and this tendency is acquired before entering university.
Lera, S. (1983).	Synopses of some recent published studies of the design process and designer behavior.	Lera (1980, in Lera 1983)) experimentally studied architects, architectural students, and non-architects and found that differences in design plans could be predicted by differences in subjective value weightings given before the design exercise.
Nadler, G. (1989).	Engineers and other professional designers.	Observational study of outstanding designers (engineer, architect, commercial artist, physician & lawyer) showed that they did NOT follow conventional methods, but rather a purpose and solution-after-next orientation.

Simmonds (1980, in Lera, 1983)	Architectural design	Studied twelve graduate students of architecture and found that they differed in their methods. Some analyzed the problem first, some generated solutions, and some looked at resources and constraints. Among those who analyzed the problem first, there was a variety of approaches. Some identified subproblems and attacked them in order of importance. Others generated a range of alternatives. A persistent problem was the inability to reverse the process of concretization. More successful students exhibited greater range and flexibility in their decisions.
Ullman, Staufer, & Dietterich (1987) in Guindon (1990)	Mechanical engineering	Designers progress from systematic to opportunistic behaviors as design evolves.
Visser (1987) in Guindon (1990)	Software design	A team of programers showed opportunistic activities due to economic use of means, postponing decisions, handling familiar components, and changing decision criteria.

Summary

Design is highly varied and complex. Skilled designers may exhibit some common tendencies but they often do not follow normative models of design. Synthetic and analytic activities are often intertwined. Experience and precedent are often determining factors in design solutions. Many studies report opportunistic behavior.

Educational/Instructional design

Instructional design as such has been little studied but there is a substantial literature on teacher planning. The classical model of curriculum planning is Tyler's. Essentially Tyler's model specifies that planning should specify goals, determine activities which address those goals, sequence the activities, and evaluate the results with respect to the goals. Empirical studies (Jackson, 1966,1968; Clark & Yinger, 1980; Zahoric, 1975) have generally found that teachers are not plan-driven but are reactive in class and that the teacher's hidden side is in the planning process. Teachers use intuitive planning and think in terms of doing. Teachers do not begin with objectives as Tyler would have them, but rather with activities. Taylor (1975) concluded teacher thinking is an inversion of theoretical thinking. Teachers first consider the context, then the situation, then the purposes.

Walker's (1971) summary of several curriculum development projects concluded similarly that objectives and even evaluation are not essential parts of curriculum development. Naturalistic views of projects indicated that objectives were a diversion or an appendix to the developers' work and not a starting point as the classical models suggest.

In an interesting use of ethno-methodology, Cain (1989) studied two preservice teachers. The two teachers were similar in background and beliefs. One was encouraged to use a "rational means-ends" planning model (based on Tyler). The other used a "Creative Planning Model" developed by Cain. The creative model consisted of three stages: preplanning, planning, and postplanning. The first stage involved observing, brainstorming, researching, and imagining a whole classroom environment. The second stage involved translating insights into goal, activities, and narratives. The last stage encouraged post hoc reflection and internalizing. The creative planner focused more on individual student characteristics, shared more teacher insights, and had more thoughts before teaching. The rational planner recalled more unplanned decisions. The creative planner reflected more after teaching. The rational planner thought of constraints as problems. The rational planner worked toward objectives even at the expense of her students. Cain suggests that the rational means-end model is not readily accepted by teachers and seems to stifle creative planning, therefore, other planning models may be desirable. Cain's data indicate that teaching results, at least, may be subject to the kinds of design methods utilized.

In virtually the *only* study in the literature on instructional design processes, Kerr (1981) studied teachers as instructional designers. Students in four summer courses worked on instructional designs and filled out questionnaires. Many reported thinking initially in terms of media rather than objectives. Students reported a high degree of uncertainty and a need to go back and reformulate objectives. Others reported that the materials suggested new possibilities. Kerr noted a general resemblance between the strategies of the teachers and the processes of artistic designers. Kerr concluded that instructional design models should encourage divergent thinking.

The only other known study of instructional designers is a dissertation by Wayne Nelson of Southern Illinois University. Nelson studied the early decision processes of four experienced instructional designers. Nelson found that while there was a discernable pattern in their methods, they did not follow Simon's top-down strategy.

As can be seen from the above, empirical studies of instructional design and teacher planning seem to indicate a strong resemblance between instructional design activities and other types of design. Instructional designers, like other designers, often do not use strongly hierarchical, top-down methods. Because of this resemblance, the results of studies of designers may have implications beyond their original domain.

Implications

Prescriptive design methodologies must support real-world methods in order to be effective. Real-world methods of instructional designers are not well understood, but if they resemble the methods of other kinds of designers, they are likely to opportunistic and non-uniform. In that case the tools we provide for instructional designers should support their preferred methods.

Guindon (1990) has argued that at least until the proper decomposition of the content is discovered the design process should be opportunistic. Only after the proper decomposition is known can a top-down approach be used. Instructional designers, like other designers, are expected to document their approach and this requires that some sort of systematic methods be reported.

Guidon has made recommendations for designers in a computer-environment:

1. The environment should not embody a method that locks designers into strict order of activities.
2. The environment should support rapid access and shifts between tools to represent and manipulate different kinds of objects.
3. It should support easy navigation between these objects.
4. The representation languages should support a smooth progression from informal to formal representations.
5. The environment should support easy editing and reorganization.
6. It should support the identification of the origin of requirements.
7. It should support the representation of interim or partial design objects.

The extent to which these recommendations apply to instructional design is unknown, but it is likely that requirements such as these will be relevant to any computer-based tools designed to support instructional design

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