Building Theory.
What, How, and Why.

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Ken Friedman

Professor of Leadership and Strategic Design
Department of Communication, Culture, and Language
Norwegian School of Management

Design Research Center
Denmark's Design School

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Abstract

Design involves solving problems, creating something new, or transforming less desirable situations to preferred situations. To do this, designers must know how things work and why. Understanding how things work and why requires us to analyze and explain. This is the purpose of theory. The article outlines a framework for theory construction in design. This framework will clarify the meaning of theory and theorizing. It will explain the nature and uses of theory as a general concept. It will propose necessary and sufficient conditions for theory construction in design. Finally, it will outline potential areas for future inquiry in design theory.

Keywords

Design research, Design science, Design theory, Philosophy of design, Theory building, Theory construction

About the Author

Ken Friedman is Professor of Leadership and Strategic Design at the Norwegian School of Management in Oslo, and at Denmark's Design School in Copenhagen. His research focuses on knowledge economy issues and organizational learning, as well as design theory and the philosophical and scientific foundations of design research. Friedman has a long-term interest in curriculum development and problem-based learning.

Friedman is also a designer and artist who had his first solo exhibition in New York in 1966. He has been active in Fluxus, the international experimental laboratory for art, design, and architecture. His work is represented in major museums and galleries around the world, including the Museum of Modern Art and the Guggenheim Museum in New York, the Tate Modern in London, and Stadtsgalerie Stuttgart.

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1.0 Design, Research, Theory

In the evolution of every field or discipline, a moment arrives when central intellectual issues come into focus. This shifts is marked by a transformation from the rough, ambiguous territory of purely practical applkication to the development of reasoned, systematic inquiry. At such a time, scholars, scientists, researchers, and their students begin to focus on such issues as research methods, methodology (the comparative study of methods), philosophy, philosophy of science, and related issues in the metanarrative through which a research field takes shape. In design research today, this also entails the articulate study of theory construction.

1.1 Definitions

To to establish a foundation for theory construction in design research, it will help to establish definitions as they are used in this article.

Most definitions of design share three attributes. First, the word design refers to a process. Second, the process is goal-oriented. Third, The goal of design is solving problems, meeting needs, improving situations, or creating something new or useful. Herbert Simon (1982: 129, 1998: 112) defines design as the process by which we "[devise] courses of action aimed at changing existing situations into preferred ones." Since this definition covers most forms of design, it is a useful starting point.

Merriam-Webster's (1993: 343) defines design as: "1a: to conceive and plan out in the mind, b: to have as a purpose: intend, c: to devise for a specific function or end 2 archaic: to indicate with a distinctive mark, sign or name, 3a: to make a drawing, pattern or sketch of, b: to draw the plans for, c: to create, fashion, execute or construct according to plan: devise, contrive…" (See also: ARTFL Webster's 1913: 397-8; Britannica Webster's 2005: unpaged; Cambridge 1999: unpaged; Friedman 2001: 36-40; Fuller 1969: 319; Link 1999: unpaged; OED Online 2005: unpaged; SOED 1993: 645; Wordsmyth 2005: unpaged.)

A taxonomy of design knowledge domains (Friedman 1992, 2000, 2001) describes the frames within which a designer must act. Each domain requires a broad range of skills, knowledge, and awareness. Design is the entire process across the full range of domains required for any given outcome. The field organized around design can be seen as a profession, a discipline, and a field. The profession of design involves the professional practice of design. The discipline of design involves inquiry into the plural domains of design. The field of design embraces the profession, the discipline, and a shifting and often ambiguous range of related cognate fields and areas of inquiry. Theorizing involves the discipline. The foundation of design theory rests on the fact that design is by nature an interdisciplinary, integrative discipline.

The nature of design as an integrative discipline places it at the intersection of several large fields. In one dimension, design is a field of thinking and pure research. In another, it is a field of practice and applied research. When applications are used to solve specific problems in a specific setting, it is a field of clinical research.

The large design field embraces six general domains. These domains are (1) natural sciences, (2) humanities and liberal arts, (3) social and behavioral sciences, (4) human professions and services, (5) creative and applied arts, and (6) technology and engineering. [Friedman 2001: 40] Design may involve any or all of these domains, in differing aspects and proportions. These depend on the nature of the project at hand or the problem to be solved. With this as a background, we are prepared to examine how – and why – theory construction is important to design, the design process, the field of design, the discipline, and the profession.

Let us return to the definition of design as the process by which we "[devise] courses of action aimed at changing existing situations into preferred ones." Those who cannot change existing situations into preferred ones fail in the process of design. There are many causes of design failure. These include lack of will, ability, or method. Designers also fail due to context or client, lack of proper training or a failure to understand the design process.

Fuller (1981: 229-231) describes design as the difference between class-one evolution and class-two evolution. Class-two evolution involves "all those events that seem to be resultant upon human initiative-taking or political reforms that adjust to the change wrought by the progressive introduction of environment-altering artifacts" (Fuller 1981: 229).

One argument for the importance of design is the increasing number of areas that are now subject to human initiative. The vast range of technologies that surround us mediate most of the human world and influence our daily lives. These include the artifacts of information technology, mass media, telecommunication, chemistry, pharmacology, chemical engineering, and mechanical engineering, along with the designed processes of nearly every service industry and public good now available other than public access to nature. Within the next few years, these areas will come to include the artifacts of biotechnology, nanotechnology, and other advanced hybrid technologies.

The artificial world increasingly affects the natural world in class-two evolution, and the world can grow worse as well as better. Design now plays a role in the general evolution of the environment, and the design process takes on new meaning. As designers take on increasingly important tasks, design has greater effects and wider scope than ever before. While the success of evolutionary artifacts and craft traditions suggests that many human beings are able to do a competent job of design, design failures are nevertheless common. The most common reasons include lack of method and absence of systematic and comprehensive understanding. These involve gaps in knowledge and preparation. It is here that research and theory play a role.

1.2. Defining Research

The noun research means, "1: careful or diligent search, 2: studious inquiry or examination; especially: investigation or experimentation aimed at the discovery and interpretation of facts, revision of accepted theories or laws in the light of new facts, or practical application of such new or revised theories or laws, 3: the collecting of information about a particular subject" (Merriam-Webster's 1993: 1002; see also: ARTFL Webster's 1913: 1224; Britannica Webster's 2005: unpaged; Cambridge 1999: unpaged; Link 1999: unpaged; OED Online 2005: unpaged; SOED 1993: 2558; Wordsmyth 2005: unpaged).

The transitive verb means “to search or investigate exhaustively” or “to do research for” something, and the intransitive verb means, “to engage in research (Merriam-Webster’s 1993: 1002; see also sources above).

The word research is closely linked to the word and concept of search. The prefix “re” came to this word from outside English. Rather than indicating the past as some have mistakenly suggested, it emphasizes and strengthens the core concept of search. The key meanings are “to look into or over carefully or thoroughly in an effort to find or discover something, to read thoroughly, to look at as if to discover or penetrate intention or nature, to uncover, find, or come to know by inquiry or scrutiny, to make painstaking investigation or examination” (Merriam-Webster’s 1993: 1059). Many aspects of design involve search and research together.

Basic research involves a search for general principles. These principles are abstracted and generalized to cover a variety of situations and cases. Basic research generates theory on several levels. This may involve macro level theories covering wide areas or fields, midlevel theories covering specific ranges of issues or micro level theories focused on narrow questions. General principles often have broad application beyond their field of origin, and their generative nature sometimes gives them surprising power.

Applied research adapts the findings of basic research to classes of problems. It may also involve developing and testing theories for these classes of problems. Applied research tends to be midlevel or micro level research. At the same time, applied research may develop or generate questions that become the subject of basic research.

Clinical research involves specific cases. Clinical research applies the findings of basic research and applied research to specific situations. It may also generate and test new questions, and it may test the findings of basic and applied research in a clinical situation. Clinical research may also develop or generate questions that become the subject of basic research or applied research.

Any of the three frames of research may generate questions for the other frames. Each may test the theories and findings of other kinds of research. Clinical research generally involves specific forms of professional engagement. In the flow of daily activity, most design practice is restricted to clinical research. There isn’t time for anything else. Precisely because this is the case, senior designers increasingly need a sense of research issues with the background and experience to distinguish among classes and kinds of problems, likely alternative solutions, and a sense of the areas where creative intervention can make a difference.

In today's complex environment, a designer must identify problems, select appropriate goals, and realize solutions. Because so much design work takes place in teams, a senior designer may also be expected to assemble and lead a team to develop and implement solutions. Designers work on several levels. The designer is an analyst who discovers problems or who works with a problem in the light of a brief. The designer is a synthesist who helps to solve problems and a generalist who understands the range of talents that must be engaged to realize solutions. The designer is a leader who organizes teams when one range of talents is not enough. Moreover, the designer is a critic whose post-solution analysis considers whether the right problem has been solved. Each of these tasks may involve working with research questions. All of them involve interpreting or applying some aspect or element that research discloses.

Because a designer is a thinker whose job it is to move from thought to action, the designer uses capacities of mind to solve problems for clients in an appropriate and empathic way. In cases where the client is not the customer or end-user of the designer's work, the designer may also work to meet customer needs, testing design outcomes and following through on solutions.

This provides the first benefit of research training for the professional designer. Design practice is inevitably located in a specific, clinical situation. A broad understanding of general principles based on research gives the practicing designer a background stock of knowledge on which to draw. This stock of knowledge includes principles, facts, and theories. No single individual can master this comprehensive background stock of knowldege. Rather, this constitutes the knowledge of the field. This knowledge is embodied in the minds and working practices of millions of people. These people, their minds, and their practices, are distributed in the social and organizational memory of tens of thousands of organizations.

Even if one person could in theory master any major fraction of the general stock of knowledge, there would be little point in doing so. The general and comprehensive stock of design knowledge can never be used completely in any practical context. Good design solutions are always based on and embedded in specific problems. In Jens Bernsen's (1986) memorable phrase, in design, the problem comes first. Each problem implies partially new solutions located in a specific context. The continual interaction of design problems and design solutions generates the problematics and knowledge stock of the field in tandem.

Developing a comprehensive background through practice takes many years. In contrast, a solid foundation of design knowledge anchored in broad research traditions gives each practitioner the access to the cumulative results of many other minds and the overall experience of a far larger field.

In addition to those who shape research at the clinical edge of practice, there are other forms of research that serve the field and other kinds of researchers develop them. Research is a way of asking questions. All forms of research ask questions, basic, applied, and clinical. The different forms and levels of research ask questions in different ways.

Research asks questions in a systematic way. The systems vary by field and purpose. There are many kinds of research: hermeneutic, naturalistic inquiry, statistical, analytical, mathematical, physical, historical, sociological, ethnographic, ethnological, biological, medical, chemical and many more. They draw on many methods and traditions. Each has its own foundations and values. All involve some form of systematic inquiry, and all involve a formal level of theorizing and inquiry beyond the specific research at hand.

Research is the "methodical search for knowledge. Original research tackles new problems or checks previous findings. Rigorous research is the mark of science, technology, and the 'living' branches of the humanities" (Bunge 1999: 251). Exploration, investigation, and inquiry are partial synonyms for research.

Because design knowledge grows in part from practice, design knowledge and design research overlap. The practice of design is one foundation of design knowledge. Even though design knowledge arises in part from practice, however, it is not practice but systematic and methodical inquiry into practice – and other issues – that constitute design research, as distinct from practice itself. The elements of design knowledge begin in many sources, and practice is only one of them.

Critical thinking and systemic inquiry form the foundation of theory. Research offers us the tools that allow critical thinking and systemic inquiry to bring answers out of the field of action. It is theory and the models that theory provides through which we link what we know to what we do.

1.3 Defining Theory

In its most basic form, a theory is a model. It is an illustration describing how something works by showing its elements in relationship to one another. Some models show the elements in a dynamic relationship by describing process or action. Others, such as taxonomy, describe relationships without describing process or action. The dynamic demonstration of working elements in action as part of a structure or the demonstration of relationship is what distinguishes a model from a simple catalogue.

Merriam-Webster (1990: 1223) defines theory as, "1: the analysis of a set of facts in their relation to one another, 2: abstract thought: speculation, 3: the general or abstract principles of a body of fact, a science or an art, 4a: a belief, policy, or procedure proposed or followed as the basis of action, b: an ideal or hypothetical set of facts, principles or circumstances – often used in the phrase "in theory," 5: a plausible or scientifically accepted general principle or body of principles offered to explain phenomena, 6a: a hypothesis assumed for the sake of argument or investigation, b: an unproved assumption: conjecture, c: a body of theorems presenting a concise systematic view of a subject."

The distinction between a science and a craft is systematic thought organized in theory. Craft involves doing. Some craft involves experimentation. Theory allows us to frame and organize our observations. Theory permits us to question what we see and do. It helps us to develop generalizable answers that can be put to use by human beings in other times and places.

This is a central issue in design. To "[devise] courses of action aimed at changing existing situations into preferred ones" on a predictable basis means understanding "things: how they are and how they work," which is Simon's (1982: 129) explanation of science. One form of design practice is allied to art and craft. It is intuitive. It sometimes produces desired results. On occasion, the intuitive practice of design produces unpredictable desirable results that can be seized retrospectively as the useable result of muddling through. Far more often, however, muddling through produces failures of two kinds. The first kind of failure involves proposals that fail in the early stages of conception or development. This is a good time for failure, since failure in conception or development eliminates potentially wasteful efforts. The second kind of failure involves completed attempts at solutions in which the designers believe that they have solved the problem even though they have not done so. This is far more costly in every sense. One of the central aspects of this kind of failure is the fact that some designers never learn that they have actually failed to meet client needs, customer needs, or end-user needs. This is because designers often end their involvement with the project before the failures arise and the clients of most failures do not return to the original designer for repair work.

Another face of design practice involves efforts to render the outcomes of design predictable. Predictability is created by the effective response to problems, and it has similarities to science, engineering, and technology. The basis of Simon's concept of design science is the idea of applicable theories of how to devise courses of action aimed at changing existing situations into preferred ones. This science is geared to industrial production, including production in the digital industries of the knowledge economy.

Industry now meets the vast majority of the world's physical needs, and industrial productivity is a necessity in a world with billions of people. Industrial production – and, therefore, design – touches nearly everything we do, use or consume. Nevertheless, the designers who plan and create industrial artifacts are not artisans. They are involved in the industrial process. Therefore, the design process is necessarily in transition from art and craft practice to a form of technical and social science focused on how to do things to accomplish goals. To meet the challenges of the design process requires understanding the actions that lead from existing situations to preferred ones. This means understanding the principles of predicting and measuring outcomes based on what W. Edwards Deming (1993: 94-118) terms profound knowledge. This knowledge is comprised of "four parts, all related to each other: appreciation for a system; knowledge about variation; theory of knowledge; psychology" (Deming 1993: 96). According to Deming (1986: 19), "Experience will answer a question, and a question comes from theory."

Theory can be described in many ways. Some theories are complex and sophisticated. Others are simple. Mautner (1996: 426) defines theory as "a set of propositions which provides principles of analysis or explanation of a subject matter. Even a single proposition can be called a theory." This often depends on the nature of the subject.

McNeil (1993: 8) proposes eleven characteristics of any general theory. 1) A theory has a constitutive core of concepts mutually interrelated with one another. 2) A theory has a mutually productive, generative connection between central concepts and the peripheral concepts where theory verges onto practice. 3) The core concepts of a theory are stated in algorithmic compression, parsimonious statements from which the phenomena in the theory can be reproduced. 4) A theory has an irreducible core of concepts, a set of concepts in which no central concept can be removed without altering the scope and productivity of the theory or perhaps destroying it entirely. 5) Two or more of the core concepts in a theory must be complementary to each other. 6) The central concepts of a theory must be well defined and must harmonize as much as possible with similar concepts of enlightened discourse. 7) The central concepts of a theory must be expressed at a uniform level of discourse. Different levels of discourse must be distinguished and used consistently. 8) More general theories (higher-level theories) must relate to less general theories (lower-level theories) and to special cases through a principle of correspondence. This principle confirms and guarantees the consistency of the more particular theories and their applications. 9) Explicitly or implicitly, a theory describes dynamic flows with contours that trace relatively closed loops as well as relatively open links. 10) A theory states invariant entities in its assumptions or formulas that provide standards for measurement. 11) Theories describe phenomena in the context of a conceptual space. This implicitly establishes a relationship between the observer and the phenomena observed.

The ability to theorize design enables the designer to move from an endless succession of unique cases to broad explanatory principles that can help to solve many kinds of problems. Warfield (in Francois 1997:100) describes the generic aspect of design as “that part of the process of design that is indifferent to what is being designed, being applicable whatever the target may be.” He contrasts this with the specific aspect of design, “that part of the design process that is particular to the target class.” Warfield (1990, 1994) identifies thirty-two basic postulates of the generic design process, which he groups under six categories: the human being, language, reasoning through relationships, archival representation, the design situation, and the design process. This generic design process is inevitably theory-rich. Theory is not entirely abstract, any more than science is abstract. Quite the contrary: sound theory requires engagement with empirical reality.

Brockhampton (1994: 507) defines theory as “a set of ideas, concepts, principles or methods used to explain a wide set of observed facts.” A designer who cannot observe facts cannot theorize them. Design requires humility in the face of empirical facts. Design based on the idea of individual genius or artistic imagination involves the externalization of internalized images. This involves a priori ideas and images. The designer comes first in this model of the design process. In contrast, solving problems demands robust engagement with the problem itself. The problem comes first.

The problem sets the premise by establishing the boundary conditions of a solution. At the same time, the problem opens a forum for the imagination and expertise of the designer. Social science depends on what Mills (1959) described as "the sociological imagination." Mathematical invention involves a journey of psychological discovery through what Hadamard (1996) termed "the mathematician's mind." Across the many fields of the natural and social sciences, progress comes when individuals and groups apply their genius to the understanding of how the world works and why. Understanding why things come to be, how they work, and why they are involves discipline and imagination both. Thus, Weick (1989) describes theory building as "an act of disciplined imagination."

2. How Theory Works

Sutherland (1975: 9) describes theory as "an ordered set of assertions about a generic behavior or structure assumed to hold throughout a significantly broad range of specific instances." To understand the nature of a behavior and organize an ordered set of assertions that describe it in a valid and verifiable way requires the characteristics described by McNeil (1993: 8).

Weick (1989) addresses the question of shaping a theory that fulfills these criteria – or similar criteria – while functioning at a sufficiently rich and non-trivial level to be useful. A body of writings equivalent to the rich literature of inquiry on theory construction in the natural and social sciences has yet to be developed in design studies. This is understandable in a discipline that is quite new compared with information science, physics or sociology, let alone philosophy, mathematics or geometry. This is also understandable in a field where the graduate programs, doctoral seminars, and research conferences that constitute the forums of theory development are just now beginning to blossom.

Having defined theory, we must ask, "What constitutes a theoretical contribution?" David A. Whetten (1989) explored this question in an article of the same title.

Whetten (1989) begins by identifying the four elements of any theory. These four elements answer six questions: 1) "what," 2) "how," 3) "why," and 4) "who-where-when." The "what" element articulates the factors that must be considered part of an explanation of the phenomena under study. Whetten identifies two criteria as central to judging the value of a "what." These are comprehensiveness and parsimony. Are all the elements identified? Are there enough elements to account for all issues without a surplus? Whetten (1989: 490) describes "sensitivity to the competing virtues of parsimony and comprehensiveness" as the mark of a good theorist.

The "how" of a theory shows how the factors identified in the "what" are related. Whetten (1989: 491) describes this as a process of using metaphorical arrows to connect the boxes in a model. This delineates the patterns that show elements of a phenomenon in their dynamic relationship to one another (Friedman 1996). This description often reveals causality, and it builds a foundation for the explanatory power of the model represented by a theory (Friedman 1996).

The "why" element involves the underlying "dynamics that justify the selection of factors and the proposed causal relationships… (t)his rationale constitutes the theory's assumptions – the theoretical glue that welds the model together… What and how describe. Only why explains" (Whetten 1989: 491).

Finally, the "who, where, and when" of a theory substantiate theory with empirical data while setting limits on its uses and applications.

According to Whetten, there are several ways to make significant contributions to theory. Discovering or amending new items in the "what" of an existing theory will generally make only a marginal improvement, but the ability to identify the ways in which the structural relationships of a theory change under the influence of new elements is often the beginning of new perspectives. New explanations – changes in the "why" of a theory – offer the most fruitful, and most difficult avenue of theory development. As an editor of a leading journal, Whetten (1989: 494-5) asks seven key questions of theoretical contributions. Of these, three apply to theory-construction in general: 1) what's new? 2) so what? 3) why so? Two of the remaining four questions involve the internal qualities of the contribution as a paper, 4) well done? and 5) done well? The last two deal with context and the field within which the contribution is offered. 6) why now?, and 7) who cares?

Theories in any field develop in a pattern of increasingly sophisticated types.

Parsons and Shils (1951: 49-51) describe several levels of theoretical systems. They state that "in one sense, every carefully defined and logically integrated conceptual scheme constitutes a 'system,' and in the sense, scientific theory of any kind consists of systems" (49). They go beyond this, to ask three questions about theoretical systems. The first question involves generality and complexity. The second involves what they call "closure," the degree to which a system is self-consistent, and the degree to which the assertions of any one part of the theory are supported or contradicted by the other parts. The third question involves what they label "the level of systematization." This involves the degree to which theory moves toward general scientific goals.

Parsons and Shils (1951: 50) propose four different levels of systematization for theories, moving from the most primitive to the most advanced. These are 1) ad hoc classification systems, 2) systems of categories, 3) theoretical systems, and 4) empirical-theoretical systems.

This implies a schema of increasingly useful kinds of theories based on the relations among the parts of a theoretical system. In Parsons's and Shils's schema, theoretical development implies a "hierarchy from ad hoc classification systems (in which categories are used to summarize empirical observations), to taxonomies (in which the relationships between the categories can be described), to conceptual frameworks (in which propositions summarize explanations and predictions), to theoretical systems (in which laws are contained within axiomatic or formal theories)" (Webster and Watson (2002: xiii).

While it is useful to distinguish between taxonomy and theory, it is fair to say that at some points, taxonomy is a kind of theory because it offers a model of existing data and demonstrates the relationships between and among facts.

The importance of taxonomy is often underestimated. An interesting case in point is the discovery of a new genus of centipede, *Nannarup hoffmani* (Bjerklie 2002: 39). The decline in taxonomic skills since the grand era of taxonomy in the nineteenth century means that it took four years between the time that Richard Hoffman decided that he had found a new kind of centipede and the final identification, classification, and naming. Hoffman attributes this to the current preoccupation with molecular biology, but he points out the problem inherent in the dearth of skilled taxonomists: “We’re coasting on the glamour of biodiversity, but losing the ability to identify the creatures on this planet” (Quoted in Bjerklie 2002: 39). This, in turn, renders theory development more difficult in several major fields, including economy, biology, and environmental studies.

Theories that describe structures offer models without moving parts. In this sense, theories are models that resemble maps or model houses.

Theories that describe processes, activities, or systems generally require dynamic descriptions. In this sense, theories are models that resemble model engines or model train sets, and they must describe motion to demonstrate the properties of the systems they resemble.

Hal Varian (1997) addresses some of these issues in a playfully titled but scientifically astute article, “How to Build an Economic Model in Your Spare Time.”

“Most of my work in economics involves constructing theoretical models,” writes Varian (1997: 1). The article discusses the challenges of theory construction and some of the approaches that Varian himself found helpful. “Over the years, I have developed some ways of doing this that may be worth describing to those who aspire to practice this art. In reality, the process is much more haphazard than my description would suggest – the model of research that I describe is an idealization of reality, much like the economic models that I create. But there is probably enough connection with reality to make the description useful – which I hope is also true for my economic models.”

Varian’s key involves representing aspects of reality in robust yet simple ways. Rather than starting with literature or seeking general features, he advocates seeking useful data on interesting issues:

“So let’s skip the literature part for now and try to get to the modeling. Lucky for you, all economics models look pretty much the same. There are some economic agents. They make choices in order to advance their objectives. The choices have to satisfy various constraints so there’s something that adjusts to make all these choices consistent. This basic structure suggests a plan of attack: Who are the people making the choices? What are the constraints they face? How do they interact? What adjusts if the choices aren’t mutually consistent?

“Asking questions like this can help you to identify the pieces of a model. Once you’ve got a pretty good idea of what the pieces look like, you can move on to the next stage. Most students think that the next stage is to prove a theorem or run a regression. No! The next stage is to work an example. Take the simplest example – one period, 2 goods, 2 people, linear utility – whatever it takes to get to something simple enough to see what is going on.

"Once you've got an example, work another one, then another one. See what is common to your examples. Is there something interesting happening here? When your examples have given you an inkling of what is going on, then you can try to write down a model. The critical advice here is KISS: keep it simple, stupid. Write down the simplest possible model you can think of, and see if it still exhibits some interesting behavior. If it does, then make it even simpler.

"Several years ago I gave a seminar about some of my research. I started out with a very simple example. One of the faculty in the audience interrupted me to say that he had worked on something like this several years ago, but his model was 'much more complex.' I replied 'My model was complex when I started, too, but I just kept working on it till it got simple!'

"And that's what you should do: keep at it till it gets simple. The whole point of a model is to give a simplified representation of reality. Einstein once said 'Everything should be as simple as possible but no simpler.' A model is supposed to reveal the essence of what is going on: your model should be reduced to just those pieces that are required to make it work."

The point of modeling – and of theory construction – is showing how things work.

3. Theory Construction Problems in Design Research

Until recently, the field of design has been an adjunct to art and craft. With the transformation of design into an industrial discipline come responsibilities that the field of design studies has only recently begun to address.

Design is now becoming a generalizable discipline that may as readily be applied to processes, interfaces between media or information artifacts as to tools, clothing, furniture, or advertisements. To understand design as a discipline that can function within any of these frames means developing a general theory of design. This general theory should support application theories and operational programs. Moving from a general theory of design to the task of solving problems involves a significantly different mode of conceptualization and explicit knowledge management than adapting the tacit knowledge of individual design experience.

So far, most design theories involve clinical situations or micro-level grounded theories developed through induction. This is necessary, but it is not sufficient for the kinds of progress we need.

In the social sciences, grounded theory has developed into a robust and sophisticated system for generating theory across levels. These theories ultimately lead to larger ranges of understanding, and the literature of grounded theory is rich in discussions of theory construction and theoretical sensitivity (Glaser 1978, 1992; Glaser and Strauss 1967; Strauss 1991; Strauss and Corbin 1990, 1994)

One of the deep problems in design research is the failure to develop grounded theory out of practice. Instead, designers often confuse practice with research. Rather than developing theory from practice through articulation and inductive inquiry, some designers simply argue that practice is research and practice-based research is, in itself, a form of theory construction. Design theory is not identical with the tacit knowledge of design practice. While tacit knowledge is important to all fields of practice, confusing tacit knowledge with general design knowledge involves a category confusion.

In recent years, designers have become acquainted with the term “tacit knowledge” articulated by Michael Polanyi (1966) in The Tacit Dimension. Proposing tacit knowledge as the primary foundation of design research reflects a surface acquaintance with the term by people who have not read Polanyi’s work.

Tacit knowledge is an important knowledge category. All professional practice – including the practice of research – rests on a rich stock of tacit knowledge. This stock consists of behavioral patterns and embodied practice embedded in personal action. Some aspects of tacit knowledge also involve facts and information committed to long-term memory. This includes ideas and information on which we draw without necessarily realizing that we do so, and it includes ideas and information that we can easily render explicit with a moment’s thought. It also includes concepts, issues, ideas, and information that can only be rendered explicit with deep reflection and serious work.

In social life and professional work, tacit knowledge is also reflected in the larger body of distributed knowledge embedded in social memory and collective work practice. Our stock of tacit knowledge enables us to practice. Putting tacit knowledge to use in theory construction requires rendering tacit knowledge explicit through the process of knowledge conversion (Friedman 2001: 44; Nonaka and Takeuchi 1995: 59-73).

Tacit knowledge is necessary for human action. Without tacit knowledge, embodied and habitual, nothing human beings do would be possible. Each action would require explicit conceptualization and planning each time. The limits on immediate attention and cognition means that it would be impossible to store and act on enough knowledge for effective individual practice in any art or science, let alone accumulate the knowledge on which a field depends (Friedman 2001: 42-44; Friedman and Olaisen 1999: 16-22). All fields of practice rest, in part, on tacit knowledge. (See, f.ex., Chaiklin and Lave 1993; Bourdieu 1977, 1990; Friedman 2001: 42-44).

To say that tacit knowledge is not research and that design theory is not identical with the tacit knowledge of design practice does not diminish the importance of tacit knowledge. It merely states that mistaken arguments about tacit knowledge as design knowledge demonstrate the confusion of the scholars who make such statements. The confusion rests on a simple failing, the failure to read Polanyi. The notion that tacit knowledge and design knowledge are identical as sources of theory development is linked with the idea that practice is a research method. Both rest on category confusions and both arguments are generally supported by references to Polanyi and Schon by scholars who have not read the works they cite.

Polanyi he settles the matter at the beginning of another book, Personal Knowledge. Where tacit knowledge is embodied and experiential knowledge, theory requires more. "It seems to me," he writes, "that we have sound reason for . . . considering theoretical knowledge more objective than immediate experience. (a) A theory is something other than myself. It may be set out on paper as a system, of rules, and it is the more truly a theory the more completely it can be put down in such terms" (Polanyi 1974: 4).

Polanyi's (1974: 3-9) discussion of the Copernican Revolution uses different language to state some of the significant themes that are seen in Varian (1997), Deming (1986, 1993), and McNeil (1993). These address such concepts as descriptive richness, theory as a guide to discovery, and modeling. As a guide to theory construction, this is also linked to Herbert Blumer's idea of sensitizing concepts (Blumer 1969; see also Baugh 1990, van den Hoonard 1997). All of these possibilities require explicit knowledge, rendered articulate for shared communication and reflection.

Explicit and articulate statements are the basis of all theoretical activities, all theorizing, and all theory construction. This true of interpretive and hermeneutical traditions, psychological, historical, and sociological traditions, and it is as true of these as of quantitative research in chemistry, descriptive biology or research engineering, logistics, and axiomatic mathematics. The languages are different. However, only explicit articulation permits us to contrast theories and to share them. Only explicit articulation allows us to test, consider, or reflect on the theories we develop. For this reason, the misguided effort to link the reflective practice of design to design knowledge, and the misguided effort to propose tacit knowledge or direct making as a method of theory construction must inevitably be dead ends.

One of the little noted points in many design research debates is the fact that reflective practice itself rests on explicit knowledge rather than on tacit knowledge. While Schon's concept of reflective practice is not a method of theorizing, (1991: 5-11), but it does raise many questions on the kinds of thinking and reflection that contribute to effective practice in many fields. Central to most of these is the struggle of rendering tacit knowledge explicit in some way. While Schon (1991: 9) suggests that there may be more possibilities for reflection than words alone, he clearly distinguishes between the epistemology of theoretical research and reflective inquiry.

Much of this confusion is linked to an ambiguous definition of design research proposed by Frayling in a 1993 paper. Frayling (1993) suggested that there are three models of design research, research into design, research by design, and research for design. Frayling is unclear about what "research by design" actually means and he seems never to have defined the term in an operational way. In a 1997 discussion (UK Council 1997: 21), he notes that it is "distantly derived from Herbert Read's famous teaching through art and teaching to art." This leads to serious conceptual problems.

Read's (1944, 1974) distinctions deal with education and with pedagogy, not with research. The failure to distinguish between pedagogy and research is a significant weak area in the argument for the concept of research by design. In addition to the difficulties this has caused in debates on the notion of the practice-based Ph.D., it also creates confusion for those who have come to believe that practice is research. The confusion rests, again, on a failure to read.

Frayling's proposal seems to be have been an effort to establish possible new research categories. As an inquiry or probe, this is a worthy effort. The problem arises among those who mistake an intellectual probe with a statement of fact. To suggest that such a category is possible does not mean that it exists in reality. Dragons may exist, but we have no evidence that they do. Medieval mapmakers created great confusion and limited the growth of knowledge for many years by filling in the empty edges of their maps with such phrases as "here there be dragons" rather than admitting, "we know nothing about what lies beyond this point."

Beyond this arises the problem of what "research by design" might mean. If such a category did exist – and it may not – the fact of an existing category would tell us nothing of its contents. Unlike dragons, we know that the planet Jupiter exists. Like the edges of the map, however, we know relatively little about conditions on the surface of the planet. Even though the laws of nature mean that some facts must be known – gravity and pressure, for example – these facts tell us little about the myriad realities that may play out depending on specific factors.

As a probe, Frayling's discussion was intended to open possibilities. Those who mistake it for a report mistake its potential value.

In one sense, however, Frayling misread Read. In adapting the surface structure of Read's terms, he failed to realize a distinction that is implicit in Read's project. This is the fact that education can be developed though the direct practice of an art. This is the case in socialization and modeling, in guild training, and it is the basis of apprenticeship (Friedman 1997: 55, 61-65; Byrne, and Sands 2002). In many situations, education and learning proceed by practicing an art or craft. One can also learn the art and craft of research by practicing research. Nevertheless, one does not undertake research simply by practicing the art or craft to which the research field is linked.

So far, the category of research by design has proven fruitless. Around the time that Frayling published his 1993 paper, Nigel Cross wrote the first of two editorials in Design Studies on the theme of research by design.

In his first editorial, Cross (1993: 226-7) points out the distinctions between practice and research and the value of connecting research to teaching and to practice.

In his second editorial, Cross notes how little progress had been made in research by design over the two years between 1993 and 1995. He writes that part of the problem involves the claim that "works of design are also works of research" (Cross 1995: 2).

Cross (1995: 3) states that the best examples of design research are: purposive, inquisitive, informed, methodical, and communicable. This requires articulation and shared knowledge within and across the field. This, again, requires articulate communication of explicit knowledge. In 1999, Cross addressed this issue again in a debate on research methods in design.

Looking back over the failed efforts of the past decade to produce valid examples of research by design, Cross (1999: unpaged) wrote, ". . . as I said in my Editorial in 1995, I still haven't seen much strong evidence of the output from the 'research for and through design' quarters. Less of the special pleading and more of the valid, demonstrable research output might help."

While the phrase "research by design" has been widely used by many people, it has not been defined. I suspect, in fact, that those who use the phrase have not bothered to read either Frayling's (1993) paper or Read's (1944, 1974) book. Instead, they adopt a misunderstood term for its sound bite quality, linking it to an ill-defined series of notions that equate tacit knowledge with design knowledge, proposing tacit knowledge and design practice as a new form of theorizing.

While these problems are relatively inconsequential outside our field, it is important to understand that they exist if we are to develop a foundation for theory construction in design research. This is why I have given them so much thought.

Again, I want to be clear on the many values of tacit knowledge. Tacit knowledge is central to all human activity, and the background of embodied individual and social knowledge provides offers the existential foundation of all activities, including intellectual inquiry. The only issue I raise here is that tacit knowledge and reflective practice are not the basis of research and theorizing. This is not to say, however, that there are no relations between those different categories of construct.

While ancient science was hypothetical and deductive, it offered no way to select among theories. While the river civilizations of Mesopotamia, Sumeria, Egypt, and China made great advances in practical knowledge, administrative routine, and professional practice in many fields, they had nothing in the way of scientific theory. Explanations were traditional and practical or mythic (Lloyd 1970: 1-23; Cromer 1993: throughout).

Thales proposed the first scientific theory when he suggested that the earth was once an ocean. While he could not test his theory, what made it scientific as contrasted with mythic was the fact that Thales proposed a natural explanation rather than a story of divine action.

Greek mathematics offered another foundation for science, and the Pythagoreans and Euclid built theories that are still used today. Again, however, there were no tests. Mathematical and geometrical theories are entirely axiomatic, and they can be tested by deduction and logic. While empirical inquiry found a few early champions in such medieval scholars as Robert Grosseteste and Roger Bacon, it was not until Francis Bacon (1999, 2000) published The New Organon in 1620 that a philosophy of science was articulated requiring a foundation in empirical observation.

At the same time, observation linked with inventive theorizing accounted for the great advances of Copernicus, Galileo, Newtown and many more. The tradition of empirical inquiry lies beneath two great activities in design: design science and reflective practice. These meet in research traditions of many kinds, including those traditions anchored in social science and critical inquiry.

Because this paper does not describe a philosophy of science, I will not explain how or why this is so, and I will not develop an argument for any specific research tradition or the kinds of theory construction on which a tradition must be established. I merely point to the fact that explicit and articulate statements are the basis of all theoretical activities, all theorizing, and all theory construction.

This true of interpretive and hermeneutical traditions, psychological, historical, and sociological traditions, and it is as true of these as of quantitative research in chemistry, descriptive biology or research engineering, logistics, and axiomatic mathematics. The languages are different. However, only explicit articulation permits us to contrast theories and to share them. Only explicit articulation allows us to test, consider or reflect on the theories we develop. For this reason, the misguided effort to link the reflective practice of design to design knowledge, and the misguided effort to propose tacit knowledge or direct making as a method of theory construction must inevitably be dead ends.

All knowledge, all science, all practice relies on a rich cycle of knowledge management that moves from tacit knowledge to explicit and back again. So far, design with its craft tradition has relied far more on tacit knowledge. It is now time to consider the explicit ways in which design theory can be built – and to recognize that without a body of theory-based knowledge, the design profession will not be prepared to meet the challenges that face designers in today's complex world.

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4. Future Directions

The goal of this presentation has been to examine criteria, approaches, and methods for theory construction in design research. To do this, I began with a foundation of definitions, using these to build a range of applicable concepts.

There is not enough room in one presentation to go beyond the general consideration of methods to a specific description of how to develop theory and build specific theories. This is a task for a future article.

Many avenues deserve exploration in the future. These include linking theory building to the perspectives of design science, proposing models of theory construction from other perspectives, generating theory from the practice of leading contemporary designers, and developing such basic tools as a bibliography of resources for theory construction and developing theoretical imagination and sensitivity.

Theory-rich design can be playful as well as disciplined. Theory-based design can be as playful and artistic as craft-based design, but only theory-based design is suited to the large-scale social and economic needs of the industrial age.

This systemic, theory-driven approach offers a level of robust understanding that becomes one foundation of effective practice. To reach from knowing to doing requires practice. To reach from doing to knowing requires the articulation and critical inquiry that leads a practitioner to reflective insight. W. Edwards Deming's experience in the applied industrial setting and the direct clinical setting confirms the value of theory to practice.

"Experience alone, without theory, teaches . . . nothing about what to do to improve quality and competitive position, nor how to do it" writes Deming (1986: 19) in his critique of contemporary manufacturing. "If experience alone would be a teacher, then one may well ask why are we in this predicament? Experience will answer a question, and a question comes from theory."

It is not experience, but our interpretation and understanding of experience that leads to knowledge. Knowledge emerges from critical inquiry. Systematic or scientific knowledge arises from the theories that allow us to question and learn from the world around us. One of the attributes that distinguish the practice of a profession from the practice of an art is systematic knowledge. In exploring the dimensions of design as service, Nelson and Stolterman (2000) distinguish it from art and science both. My view is that art and science each contributes to design. The paradigm of service unites them.

To serve successfully demands an ability to cause change toward desired goals. This, in turn, involves the ability to discern desirable goals and to create predictable – or reasonable – changes to reach them. Theory is a tool that allows us to conceptualize and realize this aspect of design. Research is the collection of methods that enable us to use the tool.

Some designers assert that theory-based design, with its emphasis on profound knowledge and intellectual achievement, robs design of its artistic depth. I disagree. I believe that a study of design based on profound knowledge embraces the empirical world of people and problems in a deeper way than purely self-generated artistry can do.

The world's population recently exceeded six billion people for the first time. Many people in today's world live under such constrained conditions that their needs for food, clothing, shelter, and material comfort are entirely unmet. For the rest, most needs can only be met by industrial production. Only when we are able to develop a comprehensive, sustainable industrial practice at cost-effective scale and scope will we be able to meet their needs. Design will never achieve this goal until it rests on all three legs of science, observation, theorizing, and experimenting to sort useful theories from the rest. To do this, design practice – and design research – requires theory.

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