Creating design knowledge: from research into practice

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Abstract
This paper considers how we create design knowledge. It examines the ways that research contributes to design knowledge in theory and in practice.

The paper will ask seven important questions:

What is the nature of design?
How does the nature of design involve knowledge of certain kinds?
What are the sources of knowledge?
How does research function as a source of knowledge?
How does research relate to other sources of knowledge?
How do we create design knowledge through research?
How does new knowledge move from research into practice?

The paper will outline answers to these questions. It will also provide information and resources for those who want to explore further.

1 Introduction

Design knowledge involves many questions. What is the nature of design? How does the nature of design involve knowledge of certain kinds? What are the sources of knowledge?

Knowledge has many sources. Research is one of them. Research also involves questions. How does research function as a source of knowledge? How does research relate to other sources of knowledge? How do we create design knowledge through research? Finally, how does new knowledge move from research into practice?

In this presentation, I will consider all these questions. I promise not to answer them, though! Answering these question is far more than an hour's work. My promise is both a reality check and guarantee that we will be done on schedule.

Along with this guarantee, however, I do promise to unfold a range of rich ideas. I'll outline issues and answers, I'll offer a few conceptual maps, and I'll present some valuable sources for those who want to go further. The main paper is followed by two endnotes that contain condensed literature reviews. The first covers the subject of knowledge. The second deals with innovation.

Now, let's start with a few basic definitions.

2 A prehistoric prelude on design and evolution

As professions go, design is relatively young. The practice of design as a thing that people do predates professions. In fact, the practice of design – making things with a useful goal in mind – actually predates the human race. Making things is one of the attributes that made us human in the first place.

It's fair to say that design began over two and a half million years ago when *homo habilis* manufactured the first tools. Human beings were designing well before we began to walk upright or attend conferences. Four hundred thousand years ago, we began the manufacture of spears. By forty thousand years ago, we had moved up to specialized tools.

Urban design and architecture came along ten

thousand years ago in Mesopotamia. Interior architecture and furniture design probably emerged with them. It was another five thousand years before graphic design and typography got their start in Sumeria with the development of cuneiform. Since then, things have picked up speed.

Today, many of us have replaced cuneiform with ASCII characters. Instead of chipping rock, we download it with Napster or Gnutella. While we haven't yet replaced our spears with pruning hooks or our swords with ploughshares, we do provide a far wider range of goods and services than the world has known before.

All these goods and services are designed. The urge to design, to take a situation, imagine a better situation, and act to create that situation goes back to those first, pre-human ancestors.

Design, in short, helped to make us human. It did so in several ways. Among the frequent misunderstandings of evolution theory is the notion that evolution somehow programmed us to become something or to behave in a certain way. This is not quite so, and the subtle distinctions are significant to how we can develop further.

The initial stimuli of evolution were random. Biological life on our planet has existed for billions of years. The many forms of life over those years shaped a rich enough environment to permit hundreds billions of different events, manifestations, behaviours, evolutionary streams. Some of those manifestations gave the creatures manifesting them competitive advantage in local environments. These creatures survived to pass their genes on. When those genes possessed the same traits, they sometimes survived to pass the genes further. When a large enough population pool existed to permit the gene-carrying population to spread, these traits sometimes spread further still into larger environments.

In earlier forms of biological evolution, all stimuli were random. Genetic endowment changed through chance. Chance arose through mutation caused by radioactive change to the genetic structure, through other forms of mutation or through some form of biological breakdown to a prior genetic structure. In the infinitely vast majority of cases, these mutations were not successful, and the creatures went extinct. Over the billions of years of life on the planet, most life forms have died out.

In some few, rare case, mutations conferred advantage on a specific life form in a specific environment. These advantages were preserved and passed on.

The environment forms the context within which initially random adaptations create successful species. Success, in the sense of evolutionary development, is not purposeful. It simply means that a species is selected for survival by the environment based on its physical and behavioural characteristics. When a mutation proved well suited to the environment, the species survived. The descendants of creatures whose characteristics were defined by beneficial mutations inherited what had once been new genetic matter. The human species and its predecessor species emerged in and adapted to a specific physical world. The physical world to which we adapted defined us.

Complexity theory (Aida *et al* 1985; Casti 1995; Waldrop 1992) offers a rich series of explanations of how adaptation takes place. One of the salient paradigms of complexity theory is the notion of the way that complex adaptive systems shape their behaviour within what is known as a "fitness landscape." As complex adaptive systems fit themselves to the landscape, the context itself takes on different shapes and meanings. Complex adaptive systems include all biological creatures: plants, animals, individual humans. They also include the communities or societies that these creatures create. Their evolutionary paths move through time and history. Some vanish, others appear. Either way, there is no going back.

At some point, life forms became sufficiently advanced to capture behavioural adaptation as well as genetic adaptation. Those creatures that adapted their behaviour in a way that

conferred evolutionary advantage did better than other creatures. The interaction between behaviour and biology, nature and nurture is complex. A creature survives better because it possesses a larger brain with a richer brain structure. The continually improving brain enables the creature's offspring to do better still. New behaviours make survival more secure. Secure survival preserves the gene pool. And so on.

This is how tool making helped us to become what we are. Tool-making probably preceded language behaviour. Tool making therefore preceded conscious imagination, the ability to imagine and to plan. Animals other than humans make tools. At the start, our ancestors – *homo habilis* – weren't humans. They were among the advanced animals that made tools.

In evolutionary terms, we developed the modern brain in the relatively recent past. The physical potential of this brain gave rise to our current habits of mind, the habits that support our mental world. The forces that give rise to the modern mind go back over two and a half million years to the unknown moment when *homo habilis* manufactured the first tools (Friedman 1997: 54-55; Ochoa and Corey 1995: 1-8).

Our tools and our tool-making behaviour helped to make us human. As tool-making and tool use became the conscious subject of willed imagination, our tools and tool-making behaviour helped us to survive and prosper as humans. There is no way to know when or exactly how we began to create conscious mental symbols, and there is no way to know exactly when symbols became our preeminent tool.

If we don't know when we began to use language, we do know when we created the first external documentation and information systems. This took place some 20,000 years ago (Burke and Ornstein 1997: 29-30).

The externalized representation of knowledge through documentation and information created a new kind of human being. The first, rudimentary information tools took the form of what archeologists call the baton, a carved bone or antler. Even in this primitive form, information tools began to "reshape the way we think" (Burke and Ornstein 1997: 29-31). This was "the first deliberate use of a device which would serve to extend the memory, because with it, knowledge could be held in recorded form outside the brain or the sequence of a ritual." The relationship between these tools and the human mind is significant, in that "the cognitive facilities needed to make the batons required a brain capable of a complex series of visual and temporal concepts, demanding both recall and recognition. These are exactly the same mental abilities which are involved in modern reading and writing."

At this point, and many points like it, the random workings of natural selection were taken over by the complex human phenotype – the properties that are caused by the interaction of genotype and environment.

In our case, this environment includes the development of culture and all that it entails. Tool making relates to the many qualities that make us human, and they all relate to tool making. These issues involve a large range of conceptual tools and symbols.

This may seem like going the long way round to get to a definition of design, but there is a reason for it, and this reason has to do with the nature of the design profession.

If, on the one hand, design helped to make us human, on the other, the act of designing has in some way been so closely linked to human culture that we haven't always given it the thought it deserves. From *homo habilis* to baton, product design precedes symbolization by just under two and a half million years. Ten or twenty thousand years is a sprint in this grand marathon. However, in exactly this sense, tool making is more deeply integrated into our behaviour and our culture than symbolization.

The Greek philosophers went to work, they devoted their attention to the relatively new tools of structured thinking rather than to the old physical tools that seemed so self-evident in the world around them. It is the everywhere

and all-the-time nature of tools, so obviously self-evident, that has obscured the importance of design rather than making it clearer.

This self-evident and everywhere, all-the-time quality of design has buried design in everything that humans think and do. For that very reason, design – a conscious profession focused on the design process – has been a long time in development.

Many of the acts of design, especially the physical acts, have been embodied in craft practice and guild tradition (Friedman 1997). These slowly evolved into a distinct practice of design only in the aftermath of the industrial revolution. The move from a practice to a profession has been more recent still. The notion of a design profession is an innovation of the twentieth century.

The idea of a design discipline is more recent still. We are still debating whether the arena of design knowledge constitutes a discipline, a field, or a science. My view is that it is, in some measure, all of these. Design entered the university curriculum in most places only during the past half century.

This development has taken different courses in different nations. In North America, for example, design courses began to enter the colleges and universities with art programmes. Most of these began in the late 1940s and since. Many – perhaps most – university-level programmes with a specific focus on design are innovations of the past two decades, as contrasted to the occasional design courses available in larger and somewhat older art programmes. In other nations, design programmes grew within and then grew out from architecture schools or technical colleges. In the United Kingdom, design entered the university when the colleges of art and design that had become polytechnics were merged into the new universities.

All these many changes were rooted in many kinds of transformation. The new location of design education in the university clarified the nature of design as a professional practice rather than a vocation or a trade. Placing design in the university also rendered visible the importance of the design profession as an important service profession in the post-industrial knowledge economy.

It is significant that design entered the university in a time of economic transition. The years between 1950 and 2000 were the years in which the economy shifted from an industrial economy to a post-industrial economy to an information society and a knowledge economy [See endnote 1]. Contemporary design takes place in this new economy – including the process of shaping artifacts through industrial design and product design.

At the same time that the development of university-level design programmes clarified the importance of the design profession, it began to make clear the gaps in our understanding of design knowledge. The emergence of a new professional training was not accompanied by the deeper understandings of ontology and epistemology that serve as the foundation of other fields.

The first professional schools located in universities were medicine, law, and theology. Admission to these schools presumed a foundation of knowledge developed in the general faculty. The professional faculties were sometimes called the higher faculties, and they were contrasted with the lower faculties in an important sense. The higher faculties trained professionals for the services of medicine, church, and state. The lower faculties provided the basis of understanding and interpretation, reason and knowledge on which society itself was established.

When art and design came into the university, they often came in as art and craft schools or professional schools. The educational foundation they offered was not the basic philosophical foundation offered for admission to the other professional schools. It was often a combination of vocational training and pre-professional education. Even colleges and universities with general education requirements sometimes cut corners in training students for art and design. In university systems that administer professional training from first admission up,

there were no corners to cut.

We find ourselves, therefore, in strange territory. On the one hand, design is anchored in a range of trades or vocations or crafts. These have never been defined in philosophical terms because they have had no basis in the work of definition. Instead, they are rooted in unspoken assumptions anchored in the inarticulate nature of a practice going back, not simply to prehistory, but rooted in our prehuman development.

On the other hand, the design profession is a contemporary field growing within the university. Having few historical roots in the philosophical tradition deeper than the last few decades, we have yet to shape a clear understanding of the nature of design. We do not agree, therefore, on whether design knowledge constitutes a discipline, a field, or a science, one of these, two or even all three. As I develop my presentation, I will explain why I see design knowledge as all three. At this point, I will simply point to the disagreement as evidence of a growing, healthy debate.

3 Defining design

The rich and growing literature in the philosophy of design makes clear that there is no longer an apparently tacit consensus on the undefined nature design that once seemed to obtain. Instead, this literature has begun to develop a deep concept of design.

This concept is being rendered explicit. Explicit conceptualization permits fruitful inquiry and reflection.

To understand the nature of design knowledge, we must define what we mean by the term design. Since there is no common and well understood definition for design, I will offer some definitions and parameters. A clear definition is vital to the issues I will address in this paper.

Design is first of all a process. The verb design describes a process of thought and planning. This verb takes precedence over all other meanings. The word “design” had a place in the English language by the 1500s. The first written citation of the verb “design” dates from the year 1548. Merriam-Webster (1993: 343) defines the verb design as “to conceive and plan out in the mind; to have as a specific purpose; to devise for a specific function or end.” Related to these is the act of drawing, with an emphasis on the nature of the drawing as a plan or map, as well as “to draw plans for; to create, fashion, execute or construct according to plan.”

Half a century later, the word began to be used as a noun. The first cited use of the noun “design” occurs in 1588. Merriam-Webster (1993: 343) defines the noun, as “a particular purpose held in view by an individual or group; deliberate, purposive planning; a mental project or scheme in which means to an end are laid down.” Here, too, purpose and planning toward desired outcomes are central. Among these are “a preliminary sketch or outline showing the main features of something to be executed; an underlying scheme that governs functioning, developing or unfolding; a plan or protocol for carrying out or accomplishing something; the arrangement of elements or details in a product or work of art.” Only at the very end do we find “a decorative pattern.” The definitions end with a noun describing a process: “the creative art of executing aesthetic or functional designs.”

Although the word design refers to process rather than product, it has become popular shorthand for designed artifacts. This shorthand covers meaningful artifacts as well as the merely fashionable or trendy. I will not use the word design to designate the outcome of the design process. The outcome of the design process may be a product or a service, it may be an artifact or a structure, but the outcome of the design process is not “design.”

Using the term design as a verb or a process description noun frames design as a dynamic process (Friedman 1993). This makes clear the ontological status of design as a subject of philosophical inquiry.

Before asking how design can be the subject of inquiry, it is useful to identify some of the salient features of the design process.

Fuller (1969: 319) describes the process in a model of the design science event flow. He divides the process into two steps. The first is a subjective process of search and research. The second is a generalizable process that moves from prototype to practice.

The subjective process of search and research, Fuller outlines a series of steps:

teleology --> intuition --> conception --> apprehension --> comprehension --> experiment --> feedback -->

Under generalization and objective development leading to practices, he lists:

prototyping #1--> prototyping #2 --> prototyping #3 --> production design --> production modification --> tooling --> production --> distribution --> installation --> maintenance --> service --> reinstallation --> replacement --> removal --> scrapping --> recirculation

For Fuller, the design process is a comprehensive sequence leading from teleology to practice and finally to regeneration. This last step, regeneration, creates a new stock of raw material on which the designer may again act. While the specific terms may change for process design or services design, the essential concept remain the same.

A designer is a thinker whose job it is to move from thought to action. A taxonomy of design knowledge domains (Friedman 1992, 2000) describes the frames within which a designer must act. Each domain requires a broad range of skills, knowledge, and awareness. Design involves more skill and knowledge than one designer can provide. Most successful design solutions require several kinds of expertise. It is necessary to use expertise without being expert in each field.

Understanding the issues these domains involve and the relationships between and among them offers a useful framework for considering design knowledge (See Figure 1).

To work consciously with the relationships among the several domains and areas of design knowledge requires systemic thinking. The designer is one member of a team or network that generally involves several elements described by the matrices implicit in the taxonomy. Here arises a difficulty.

When we speak of manufacturing complex industrial products or shaping complex services, we necessarily involve a large network of interacting systems. When the process works well, nearly every part of the system in some way affects every other part of the system. When parts of the system affect each other adversely, the entire system suffers. Again, this emphasizes the role of designer as thinker and planner. Organization theory suggests building teams or networks to engage the talent for each problem. In today's complex social and industrial environments, the designer works in teams or heads teams.

Systemic thinking gives perspective to the models of design offered here. The designer is neither the entry-point nor pivot of the design process. Each designer is the psychological centre of his own perceptual process, not the centre of the design process itself. The design process has no centre. It is a network of linked events. Systemic thinking makes the nature of networked events clear. No designer succeeds unless an entire team succeeds in meeting its goals.

Herbert Simon defines design in terms of goals. To design, he writes, is to "[devise] courses of action aimed at changing existing situations into preferred ones" (Simon 1982: 129). Design, properly defined, is the entire process across the full range of domains required for any given outcome.

The nature of design as an integrative discipline places it at the intersection of several large fields (See Figure 2). In one regard, 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.

One model for the field of design is a circle of six fields. A horizon bisects the circle into fields of theoretical study and fields of practice and application.

Domains of Design Knowledge: a Taxonomy

Domain 1: Skills for Learning and Leading	Domain 2: The Human World	Domain 3: The Artifact	Domain 4: The Environment
Problem Solving **Interaction Method** **Coaching** **Mind mapping** **Research Skills** **Analysis** **Rhetoric** **Logic** **Mathematics** **Language** **Editing** **Writing** **Presentation Skills** Public speaking Small group Information graphics	**The Human Being** Human behavior Information semantics Knowledge creation Physiology & ergonomics Research & methodology **The Company** Organizational management & behavior Business economics Company culture Leadership Administration Future planning Process management Change management Process skills Company functions Governance Logistics Production Marketing Finance **Society** Trends Legal issues Media Social economics Communication **The World** World trade European Union USA Asia Cross-culture Issues Political economics **Theory Basics** Culture theory Sociology of knowledge Reception theory History of design Sociology of taste Content analysis World history Paradigm analysis Models	**Product Development** Methodology Market research Innovation research Problematics Product generation Creating new products Transforming old products Product regeneration Correcting problems Improving products Positioning Re-engineering (lean production) **Design** Product design Ergonomics Product semantics Product graphics Functionality Graphic design Visual ergonomics Typography Corporate design Behavioral design Information design Knowledge design Process design **Manufacturing** Technology Operations Statistical quality control Logistics Process management	**Natural Environment** Ecology Evolution Environment Impact **Built Environment** Cityscape Economy Social web Infrastructure Traffic Telecommunication Airports Food distribution Human ecology **Architecture** Informated buildings Usage Architecture as idea Architecture as corporate identity Profile architecture **Interior** Furniture Interior as corporate identity Psychology Function Social structure The shape of work The shape of play The shape of private life **Installation** Philosophy of space Culture theory Art ideas Inquiry

Figure 1 Domains of design knowledge

Figure 2 Model of the field of design

The triangles represent six general domains of design. Moving clockwise from the left-most triangle, these domains are (1) natural sciences, (2) humanities and liberal arts, (3) social and behavioural sciences, (4) human professions and services, (5) creative and applied arts, and (6) technology and engineering.

Design may involve any or all of these domains, in differing aspect and proportion depending on the nature of the project at hand or the problem to be solved.

The taxonomy of design knowledge and the generic model of design raise implications for design research. These also involve understanding the kinds of knowledge that form a foundation for the research act. This, in turn, will reveal how knowledge moves from research into practice.

Before we focus on design research, I will consider the subject of knowledge itself.

4 What is knowledge?

Merriam-Webster defines knowledge as "2 a (1) : the fact or condition of knowing something with familiarity gained through experience or association (2) : acquaintance with or understanding of a science, art or technique b (1) : the fact or condition of being aware of something (2) : the range of one's information or understanding <answered to the best of my knowledge> c : the circumstance or condition of apprehending truth or fact through reasoning : cognition d : the fact or condition of having information or being learned <a man of unusual knowledge> 4 a : the sum of what is known : the body of truth, information and principles acquired by mankind b (archaic) : a branch of learning.

"Synonyms: knowledge, learning, erudition, scholarship mean what is or can be known by an individual or by mankind. Knowledge applies to facts or ideas acquired by study, investigation, observation or experience <rich in the knowledge of human nature>. Learning applies to knowledge acquired especially through formal, often advanced, schooling <a book that demonstrated vast learning>. Erudition strongly implies the acquiring of profound, recondite or bookish learning <an erudition unusual even in a scholar> . Scholarship implies the possession of learning characteristic of the advanced scholar in a specialized field of study or investigation <a work of first-rate literary scholarship>" (Merriam-Webster 1993: 647).

Gregory Bateson (1984: 41) once said that "information is any difference that makes a difference." In reality, the power to make a difference defines the difference between information and knowledge. Roger Bacon, the 16th century scholar and a founder of the scientific method, noted this difference in his Religious Meditations, Of Heresies, where he wrote that, "knowledge itself is power" (in Mackay, 1991: 21). Peter Drucker respects that difference, too, and describes the transformation of information into knowledge: "Knowledge is information that changes something or somebody — either by becoming grounds for action, or by making an individual (or an institution) capable of different and more effective action." (Drucker, 1990: 242)

Knowledge embodies agency and purpose. In this, it differs from information (Friedman and Olaisen 1999). Information may be stored in information systems. Knowledge is embodied in human beings. Knowledge creation is an intensely human act.

To understand the role of research in knowledge creation, it is ultimately necessary to reflect on what philosophers call "the problem of knowledge." Mario Bunge (1996: 104) states that the problem of knowledge is "actually an entire system of problems. Some of the components of this system are: What is knowledge? What can know: minds, brains, computers, or social groups? Can we know everything, something, or nothing? How does one get to know: from experience, reason, action, a combination of two, or all three, or none of them? What kind of knowledge is best – that is, truest, most comprehensive, deepest, and most reliable and fertile? These five problems constitute the core problematics of epistemology, or the 'theory' if knowledge – which is still to become a theory proper."

These issues are the cores of an entire discipline. In a short presentation, it is not possible to do more than acknowledge the fact that a problematics of knowledge exists. This series of problems has much to do with understanding what knowledge is and how knowledge is created. This is a central field of inquiry for a relatively new research field such as design. Bunge (1996) and Alvin I. Goldman (1999) have addressed the problem of knowledge in ways that can be extraordinarily valuable to us. Here, I will simply state that it is vital for us to recognize the importance to

our field of the problem of knowledge. Our understanding of design has grown and developed in recent years. Our understanding of knowledge much become richer still if we are to apply the problem of knowledge to design. It is through this work that we will develop a proper understanding of what will be required to generate design knowledge.

The definitions of knowledge and design offer a basis for definitional reflections on design knowledge that form the foundation of what follows.

5 Experiential and reflective knowledge

Design is a process. The design process is rooted in and involves both theoretical disciplines and fields of practice. As all fields of practice do, design knowledge involves explicit knowledge and tacit knowledge. Disciplines are also practices, and they, too, involve explicit knowledge and tacit knowledge both. The challenge of any evolving field is to bring tacit knowledge into articulate focus. This creates the ground of shared understanding that builds the field. The continual and conscious struggle for articulation is what distinguishes the work of a research field from the practical work of a profession.

Professional excellence requires articulation. This means rendering tacit knowledge explicit. This is the foundation of what Nonaka and Takeuchi (1995) describe as the knowledge creation cycle. This is also the basis of Schon's concept of reflective practice. Reflective practice is not a form of silent meditation on work. In reflective practice, reflection takes the form of bringing unconscious patterns and tacit understandings to conscious understanding through articulation. This is related to the therapeutic process. It is related to the way that therapists work with supervisors and to the way that teachers work with master teachers. It is related to the dialogue between professionals in training and their mentors.

Schon (1983, 1990), Argryis and Schon (1992), and Argyris (1961, 1968, 1982) address these issues in their books and articles on professional development through reflective practice and rich learning cycles. This is also the basis of discussion teaching (Christensen, Garvin and Sweet 1991) and case method teaching (Barnes, Christensen and Hansen 1987).

These issues are subtle and require care. All domains of human knowledge embody some form of tacit knowledge. Even the most articulate fields involve assumptions, shared experience, and personal development. All these create a background of tacit knowledge that can never be fully stated.

In many ways, this tacit knowledge forms a central basis for any kind of work.

As Bunge (1996: 104-107) suggests, knowledge arises through the interaction of many forms of learning. Thinking, experience and action all play a role. Although the process of learning and the nature of knowledge are not completely understood, there is wide agreement that knowledge creation requires experience. Kolb's (1984: 38) definition of learning as "the process whereby knowledge is created through the transformation of experience" offers a useful perspective.

Any kind of experience may, in principle, be transformed into knowledge. Kolb emphasizes the relationship between experience and knowledge as a dynamic process of continuous reproduction and regeneration. It contradicts the static model of learning as acquiring knowledge external to and independent of the learner. Information and facts are external to and independent of the learner. Knowledge inheres in human beings and the specific form of knowledge is often contingent on the learning process.

Because knowledge is human, developing knowledge requires thinking and practice, mind and body both. Mindless recording will not transform experience into knowledge. Learning requires human agency, a concept synonymous with Heidegger's concept of care, the human tendency for each person to care about his own existence (Heidegger 1993: 238). For Heidegger, both practical knowledge and theoretical knowledge express of human care in an intimate relationship between action

and knowledge.

Human knowledge is not only the product of past experience, but also the product of anticipating the future. Knowing things involves feedforward as well as feedback, anticipating how things may be used, manipulated or acted on in the future. As children, we all discover that anticipatory knowledge – prediction – is not always accurate. Politicians and scientists know this, too. It is part of the knowledge cycle nonetheless.

Kolb's definition of learning fits together with Heidegger's concept of care to suggest a model of individual learning that shifts the focus of learning from the adaptation of external behaviour to the internal process of knowledge creation. The model outlines the ways in which human beings monitor and control knowledge through three human capacities. These capacities are 1) the ability to act, 2) the ability to apprehend action and the environment within which action takes place, 3) critical comprehension.

Kolb (1984: 107) writes that, "Comprehension ... guides our choices of experience and directs our attention to those aspects of apprehended experience to be considered relevant. Comprehension is more than a secondary process of representing selected aspects of apprehended reality. The process of critical comprehension is capable of selecting and reshaping apprehended experience in ways that are more powerful and profound. The power of comprehension has led to the discovery of ever new ways of seeing the world, the very connection between mind and physical reality." Critical comprehension is the pivotal force in learning.

This process integrates experience into knowledge through cycles of action and feedback. Knowledge, in turn, supports the human capacity to understand present situations and shape future action. Experience is transformed into knowledge in several ways. One is reflection on the past. The other is the strategic judgment that human agents make as they design the future. These judgments link human beings to the environment by projecting future possibilities in a complex network of cause and effect. Things are understood through their perceived positions in these networks.

The interaction between experience, anticipation, critical comprehension, and knowledge is only part of the story. Situated knowledge also relies on generalized knowledge distinct from – and abstracted from – immediate situations and intentions.

Generalized knowledge guides perception and thus it guides action. It is common knowledge shared among groups of actors. Community among actors depends, in part, on shared common knowledge and the shared nature of general knowledge implies a social process. This social process plays a major role in knowledge creation. While individual actors also create generalized knowledge, every creator of new knowledge builds in part on what has come before. Even the greatest individual creators see farther because they stand, as Newton famously put it, "on the shoulders of giants." Even individual knowledge creation is thus a social process.

Two more aspects of human agency drive knowledge creation, habit, and tacit knowledge. Garfinkel's (1967) experiments demonstrate that a general store of knowledge is essential even to the most mundane activity. This general store of knowledge depends on many factors. These include habituation, tacit knowledge, and the larger social stock of generalized knowledge, together with learning based on experience, anticipation, and critical comprehension.

One fascinating aspect of habitualization is the fact that it plays a role in many different theories of knowledge creation. Berger and Luckman (1971: 70-71) write that, "All human activity is subject to habitualization. Any action that is repeated frequently becomes cast into a pattern, which can then be reproduced with an economy of effort and which ipso facto, is apprehended by its performer as that pattern ... In terms of the meanings bestowed by man upon his activity, habitualization makes it unnecessary for each situation to be defined anew, step by step. A large variety of situations

may be subsumed under its predefinitions."

Habitualization need not prohibit critical comprehension. The two processes work together in dialectical relationship. They are distinct yet related dimensions of learning that depend intimately on each other. One form of habitualization results from repeated acts of critical comprehension that transform experience into knowledge. Critical comprehension depends on a generalized store of knowledge generated by habitualization. The knowledge spiral describes the relationships between these aspects of knowledge.

The knowledge management framework posits knowledge creation as a spiral moving through epistemological and ontological dimensions (Nonaka and Takeuchi 1995: 70-73). The epistemological dimension can be portrayed as a spectrum running from explicit knowledge to tacit knowledge. The ontological dimension describes levels of knowledge moving from individual knowledge through group knowledge, organizational knowledge, and inter-organizational knowledge. One can extend the scale to social and cultural knowledge.

Human beings shift knowledge from one frame to another. As they do so, they embrace knowledge, enlarging it, internalizing it, transmitting it, shifting it, recontextualizing and transforming it. Humans create new knowledge by acting on and working with knowledge. Knowledge creation requires social context and individual contribution. This involves an effort to render tacit or unknown explicit and known.

6 Theory and research

The difficulty of fitting research into the field of design is not rooted in the nature of design. Neither is it rooted in the nature of design knowledge. The great difficulty arises from a field of practice with a huge population of practitioners who were trained in the old vocational and trade traditions of design. This is, in part, to be expected in a profession so new to the university.

This situation is visible in many simple demographic facts. It is reflected in the fact that few university design teachers have had a broad university background. It is reflected in the fact that doctoral programs in design are developing at a pace that far surpasses the availability of trained research faculty – and it is reflected in the shortage of design professors and doctoral supervisors who have, themselves, earned a PhD. The demographics of design programs reveal many similar problems and challenges. The fact that we are coming to recognize these challenges as problems is, in itself, an important step forward. Diagnosis precedes cure.

These problems are not, however, the fault of craft practice. Quite the contrary. Craft practice is eminently suited to reflective practice. Craft practice is also well suited to theory development and research.

We are now seeing an increasing number of craft practitioners who also generate significant research. Some of the work emerging from this field is so significant that it is helping to revolutionize research methods training in other fields. An important example is seen in the work of Pirkko Anttila.

Pirkko Anttila, a professor in craft research, has become central in defining the challenges of research methodology in design. Anttila's (1996) book promises to revolutionize the learning and use of research methods by designers. The book is rooted in a rich, structural approach that assesses design methods in terms of challenges, needs, and desired outcomes. The book enables the individual reader to locate and begin to explore a variety of research concepts through a pedagogically sophisticated program of accessible self-learning. At the same time, the comprehensive overview makes this book a helpful guide to experienced researchers. Researchers in social science, management, and economics as well as in art, craft, and design are using the Finnish edition.

The problems that arise in a population of craft practitioners (Friedman 1997) have to do with educational traditions rather than subject matter. This involves the failure of educators and practices in the arts and crafts – including

design – to keep up with the knowledge revolution.

This is a sad paradox. Artisans and shop-floor engineers were leading actors in the industrial revolution. Artisans and artisan engineers helped to develop the foundations of industrial practice. Some played important roles in the birth of new approaches to education and learning. A few — such as bookbinder Michael Faraday or printer Benjamin Franklin — even played a role in the birth of modern science.

The problem we face today is that arts and crafts training – and design training in the art schools – is rooted neither in the rich craft tradition nor in the research tradition of the universities. This gives rise to a culture of people who mistake silence for tacit knowledge and confuses unreflective assertion with reflective practice.

The immature state of the academic discipline and the immature state of the profession in a knowledge economy are two causes of failure in design practice.

Successful design practice requires a rich foundation in experience. Successful design also requires explanatory principles, models, and paradigms. The design profession has developed few of these. Achieving desired change requires a foundation in theory. This demands a conception of preferred situations in comparison with other possible situations and an understanding of the actions that lead from a current situation to a preferred one. General principles are required to predict and measure the outcome of decisions. This is what W. Edwards Deming (1993: 94-118) terms profound knowledge, comprised of "four parts, all related to each other: appreciation for a system; knowledge about variation; theory of knowledge; psychology" (Deming 1993: 96).

The fact that design is young poses challenges to the development of a rich theoretical framework. In order to develop this framework, a community of researchers must identify themselves and enter dialogue. This process has only recently begun. In the development of a professional research community, "...discussion about the scope and content of a young field of research helps to form the identity of its scientific community. Internal organization and boundary definitions are central means for the social institutionalization of a specialty. The exchange of opinions and even disputes concerning the nature and limits of a field help to construct identity and thus become bases for social cohesion" (Vakkari 1996: 169).

In this context, "conceptions of the structure and scope of a discipline are social constructs that include certain objects within that domain and exclude others. Depending on the level of articulation, the outline of a discipline dictates what the central objects of inquiry are, how they should be conceptualized, what the most important problems are and how they should be studied. It also suggests what kinds of solutions are fruitful. Although articulation is usually general, it shapes the solutions to specific research projects. This general frame is the toolbox from which researchers pick solutions without necessarily knowing they are doing so" (Vakkari 1996: 169).

The concept of profound knowledge establishes prerequisites for a toolbox of design knowledge that will permit broad understanding linked to predictable results.

Some kinds of design function within well-defined domains such as industrial design, graphic design, textile design or furniture design. Other forms of design involve several design disciplines and several professions. These include information design, process design, product design, interface design, transportation design, urban design, design leadership and design management.

No single factor determines the location of any given design practice in a specific domain. In today's knowledge economy, therefore, designers must maintain a broad general perspective linked to a range of specific skills in leadership, learning, analysis, knowledge acquisition, research, and problem solving. [See figure 1] The demands of the knowledge economy distinguish design professionals from the design assistants who execute

specific applications required by the design process.

Intelligent designers are moving beyond craft skill and vocational knowledge to professional knowledge. They do this by integrating specific design knowledge with a larger range of understandings. This includes understanding the human beings whose needs the design act serves. This includes understanding the social, industrial and economic circumstances in which the act of design takes place. This includes understanding the human context in which designed artifacts and processes are used. Intelligent designers also develop general knowledge of industry and business. A broad platform enables designers to focus on problems in a rich, systemic way to achieve desired change.

Research is one source of the knowledge that designers require.

7 What is research?

Britannica Webster's defines research with elegant simplicity. The first definition dates from 1577:

> "re·search noun Etymology: Middle French recerche, from recerchier to investigate thoroughly, from Old French, from re- + cerchier to search — more at SEARCH Date: 1577 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" (Britannica Webster's 1999: unpaged).

The second appears only a few years later:

> "2 research Date: 1593 transitive senses 1 : to search or investigate exhaustively <research a problem> 2 : to do research for <research a book> intransitive senses : to engage in research" (Britannica Webster's 1999: unpaged).

The discussions of research in design that label research as a purely retrospective practice have been misleading. Statements that conflate research with positivism are equally misleading. So, too, are essays that proclaim systematic, rigorous research to be inflexible or uncreative. One recent note asked plaintively, "where's the search in research?" as though rigorous research involves little more than tedious cataloguing of established facts. Many aspects of creative research are tedious, but that's also true of painting, music, and dance.

Without developing a comprehensive linguistic analysis of the word research, I will simply note that the prefix "re" came to this word from origins outside English. The prefix doesn't seem to modify the core word in the direction of past or retroactive conditions, but it seems, rather, to emphasize or strengthen it in some way.

As the dictionaries note (Merriam-Webster's 1990, 1993: 1002; Britannica Webster's 1999: unpaged), the meanings of research are closely linked to the senses of search in general, "Middle English cerchen, from Middle French cerchier to go about, survey, search, from Late Latin circare to go about, from Latin circum round about — more at CIRCUM- Date: 14th century transitive senses 1 : to look into or over carefully or thoroughly in an effort to find or discover something: as a : to examine in seeking something <searched the north field> b : to look through or explore by inspecting possible places of concealment or investigating suspicious circumstances c : to read thoroughly : CHECK; especially : to examine a public record or register for information about <search land titles> d : to examine for articles concealed on the person e : to look at as if to discover or penetrate intention or nature 2 : to uncover, find, or come to know by inquiry or scrutiny — usually used with out intransitive senses 1 : to look or inquire carefully <searched for the papers> 2 : to make painstaking investigation or examination" (Britannica Webster's 1999: unpaged)."

One can say that many aspects of design involve search and research both. Here, I will draw on Richard Buchanan's distinction between basic research, applied research and

clinical research.

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 macrolevel theories covering wide areas or fields, midlevel theories covering specific ranges of issues or microlevel theories focused on narrow questions. Truly general principles often have broad application beyond their field of original, and they may have surprising predictive power arising from their generative nature.

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 microlevel 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. In fact, any of the three frame of research may generate questions for the other fields, and each may test theories and findings from the other kinds of research. It is important, however, to note that clinical research generally involves specific forms of professional engagement.

In the rough and tumble of daily practice, most design practice is restricted to clinical research. There simply isn't time for anything else.

In today's complex environment, a designer must identify problems, select appropriate goals, and realize solutions. A designer may also assemble and lead a team to realize goals and solutions. Today's designer works on several levels. The designer is an analyst who discovers problems. 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 ensures that the right problem has been solved.

A designer is a thinker whose job it is to move from thought to action. The designer uses the capacities of mind in an appropriate and empathic way to solve problems for clients. Then, the designer works to meet customer needs, to test the outcomes and to follow through on solutions.

Here, we see the first value of research training for the professional designer. Given the location of design practice in a specific, clinical situation, a broader understanding of general principles gives the practising designer a background of principle and theory on which to draw. This comprehensive background will never arise in any immediate situation. Developing this background in the field of practice takes 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.

I will consider this issue later in discussing how we move from research into practice.

Before asking what value research offers to practice, it might be valuable to attempt a summary definition of research.

In the shortest form, 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.

What distinguishes research from reflection? Both involve thinking. Both seek to render the unknown explicit. Reflection, however, develops engaged knowledge from individual and group experience. It is a personal act or a community act, and it is an existential act. Research, in contrast, addresses the question

itself, as distinct from the personal or communal. The issues and articulations of reflective practice may become the subject of research, for example. This includes forms of participant research or action research by the same people who engaged in the reflection that became the data. Research may also address questions beyond or outside the researcher.

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. The methods and traditions on which they draw are many and several. Each has its own foundations and values. Nevertheless, all involve some form of systematic inquiry, and all involve a formal level of theorizing and inquiry beyond the specific research at hand.

This systemic 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, one requires the articulation and critical inquiry that allows a practitioner to gain 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 management nothing about what to do to improve quality and competitive position, nor how to do it" writes Deming (1986: 19). "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, therefore, 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.

As artists, we serve ourselves or we serve an internalized vision that is, for all practical purposes, a form of the self. In the professions, we serve others than ourselves. 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 reasonably predicable – changes to reach them. Science is a tool for this aspect of design, and research is the collection of methods that enable us to use the tool.

8 Reasons for research

There are many reasons for research, basic, applied, and clinical. These include: curiosity; the desire to know something; the desire to know why something is; the desire to know how something works; the need to solve a problem; the desire to serve a client. There are also practical reasons for research. For university faculty, this includes the requirement that we publish. On the surface, this is simply a career requirement. At a deeper level, the research requirement is based on a simple fact. Those who create knowledge through research have a different and richer relationship to their subject field than those who simply teach the knowledge that others create.

Research has always been closely linked with science. Simon's (1982: 129) definition of the goal of science in general is understanding "things: how they are and how they work." This is the goal of science in its larger sense of systematic knowledge. This is why some cultures use the term "science" to cover many disciplines or field of inquiry other than natural or social science. In the sense of understanding how things are and how they work, literature, history or theology can also be seen as sciences.

Campbell, Daft, and Hulin (1982: 97-103) outline the basis for successful research. Successful research requires active research

practice and lively involvement with colleagues. Successful research is frequently marked by convergence. Ideas, methods, interests, problems and techniques interact in the work of a researcher. Good research is often intuitive, based on a sense that the time is right for an idea. (This criterion, of course, is more easily seen in hindsight, since research ideas for which the time is not right tend to vanish.) Successful research arises from concepts and leads to theorization and theoretical understanding.

Robson (1993: 26) emphasizes the real world value of successful research, with problems "arising from the field and leading to tangible and useful ideas."

Here, I will assert the value of free inquiry and basic research, research that is not always concerned with immediate results identified in terms of the "real world."

Free inquiry and science have their uses, even in service professions such as design. They are especially useful as a foundation for improvements to practice.

Science – vetenskap, wissenchaft – is systematic, organized inquiry and all the domain of theory-based thinking on design constitute some form of science in this larger sense. Scientific method in the restricted sense used for natural science has its uses, too. In the sense that scientific inquiry can contribute to design, it can, indeed match some of the goals of the design discipline. No one has suggested scientific inquiry can meet all the goals of design. Where science in the large sense or scientific method in the narrow sense can be used, however, they should be used.

Design is both a making discipline and an integrated frame of reflection and inquiry. This means, that design inquiry seeks explanations as well as immediate results.

One way to build better artifacts or cause change in a desired direction is to understand larger principles. This requires philosophy and theory of design linked to general explanation. I don't demand that everyone pursue this kind of research. If design research is to be restricted to narrow, immediately practical goals deemed acceptable to practitioners and judged only by practitioners, there's no evident purpose to much of the most interesting work in design research today.

But, then, if design research is to be restricted to narrow, immediately practical goals deemed acceptable to practitioners, there would have been no purpose to much of the work of several significant scholars in design, in engineering or industrial practice. Some of the figures of whom this is true are W. Edwards Deming, Donald Schon, Buckminster Fuller, Victor Papanek, Henry Petroski and Edward Tufte.

There are powerful theoretical arguments for research and explanation. The evidence of design research and design practice also supports these ideas.

Explanation is a profound source of better application. While applications lie in the realm of practice, explanation lies in the realm of science. To expand the frame of knowledge within which better applications emerge, we require profound explanations and the freedom to seek them in pure form.

Many design researchers – and some designers – seek to understand the world to explain it. Let's consider why a robust design process requires understanding to explain. To use Simon's (1982: 129) elegant definition, to design is to "[devise] courses of action aimed at changing existing situations into preferred ones." Why would we require an explanatory design science for this to happen? To change existing situation into preferred ones, we must understand the nature of preferred situations and the principles through which we achieve them. This means, in Simon's (1982: 129) words, understanding "things: how they are and how they work."

The best argument for the importance of understanding how things are and how they work is the frequent failure of design outcomes. Unintended consequences and performance failures result most often from a failure to understand how things are, how they work, and – more important – a failure to

understand the linkages between designed processes or artifacts and the larger context within they are created and found.

Design activity involves goals other than natural, physical, and social science. It also involves some of the same goals. What is different in design is that the framework of inquiry is both interdisciplinary and integrative. The larger frame of design involves issues that are different from the sciences and it involves issues that are explicitly parallel. Explanation is not our only goal. It is often among our goals. In some forms of design research, it may well be the essential goal of a specific inquiry.

Explanatory power is also the fuel of better practice.

Ideas and projects that do not work mark every growing field of inquiry. Methods, theories, even historical accounts, and interpretative frames begin as proposals. These proposals begin in some form of idea or inquiry or even in some form of intuition or inspiration. The professions, technology, the humanities, social science, and natural science are all littered with ideas that seemed promising to someone. Proposing ideas must always be free: once proposed, the ideas must be subject to critical inspection, application and perhaps even testing to see which work.

The logic of idea generation involves intuition and deduction as well as induction and abduction. Kepler got to his laws of planetary motion the long way round, starting with trying to fit the orbits of the planets to everything from music scales to a strange Pythagorean model of nested Platonic solids. By testing these against observational data, he eventually developed a series of laws that explain the model of the solar system we have used ever since. This, in turn, led to Newton's work.

The earlier predictions of Ptolemaic astronomy worked perfectly well for the practitioners of the day. While the Copernican model of the solar system was essentially better than the Ptolemaic model, Copernicus relied on an Aristotelian doctrine that uses perfect circles to describe celestial orbits. Since the planetary orbits are not circular, the original Copernican model was less accurate than the Ptolemaic model with its rich catalogue of documented and precise observations. Practitioners found Ptolemaic astronomy far more useful and accurate than Copernican astronomy. The two systems competed for over a century after the publication of Copernicus's Revolutions. Many argued, correctly, that Ptolemaic astronomy was the better system. Despite its lack of mathematical elegance, it was far superior in predictive power. That made it superior to practising astronomers and astrologers. (The largest group of practitioners using astronomical observations was astrologers.)

For decades, the Copernican model was a strange theoretical artifact with no practical value. Although the Copernican solar system is essentially the correct model, it was deeply flawed in practical terms.

Einstein's theorizing began with discrepancies in the implications of theory. Maxwell's laws implied a profound problem regarding the invariant nature of the speed of light contrasted against the position of the observer. This is the same problem made clear by the Michelson-Morley experiments, though Einstein began with the theory and not with the Michelson-Morley observations.

By taking one or two implications of Maxwell's equations at face value, Einstein reached a stunning new kind of proposal. This proposal took the form of special relativity. Here, Einstein was clear. Theory and hypotheses arise from intuition and the free play of the mind. Theory must then be tested against empirical data. In Einstein's case, theory contradicted what many physics practitioners believed to be common sense.

No one denies the important of practice. I merely assert that in many cases, the research that seems to serve practice in the short term often fails to serve the long-term needs of a field. In failing to serve significant long-term needs, research restricted to that which seems practical and applicable in today's terms fails to serve the best interests of practitioners.

One of the reasons universities exist — and one of the values of basic research — is generating vital knowledge outside the immediate constraints of practice.

9 When practice doesn't want research

Even so, there are occasions when practice doesn't want research. Sometimes, whether things work or not, it doesn't matter. Many of Philippe Starck's artifacts meet this criterion. The lemon squeezer where the juice runs off down the legs and the kettle that burns the hand in the act of pouring are good examples of these. I have now heard that Alessi actually offers a guarantee that some Starck artifacts won't work. The guarantee of dysfunction is supposedly part of the market appeal. I imagine that the next item out will be a prefilled water kettle, sealed and guaranteed to explode, destroying the stove and injuring the cook in the process.

Practitioners sometimes reject vital streams of research while seeking solutions that do work. One of the best known episodes of this behaviour comes from medicine rather than design.

In the middle of the 19th century, medical practitioners believed that research into antiseptic practice or bacteria had no practical value.

A brief look at the history of antiseptic treatments of different kinds makes the case. Semmelweiss, Lister and Pasteur had rough going. Semmelweiss, incidentally, got his initial ideas as an intuition that he tested with a simply, rule-of-thumb procedures that were essentially statistical in nature.

Medical research of that era made small advances. These pioneers made the greatest advance of the era with work that was bitterly resisted by practitioners. medical practitioners thought this stream of inquiry had no value. It is nevertheless possible that the medical innovations arising from this work was the most significant advance of the past two millennia in terms of numbers of lives saved in medical practice and clinical application. There have been more astonishing innovations. Many advances have been more dramatic. No single advance did more for health through preventive care than the introduction of antiseptic procedures and pasteurization of food.

Effective design research must be an act of free choice. Each researcher is free to decide what goals his or her research will serve. Some design research ought to serve practice. Not all design research should be required to serve practice.

When a form of research is tied too closely to the practice of any specific era, it is — by definition – often incapable of creating the new knowledge of the future. It leads to incremental improvements more often than breakthrough. Since we do not know what knowledge may be useful in the future, demanding that we exclusively serve today's perceived needs will not advance a field.

Campbell, Daft, and Hulin (1982: 102) also outlined the reasons that are often associated with unsuccessful research. Several of these reasons involve research done for motives other than genuine curiosity. Research undertaken purely for publication, for money or funding is among these. A research theme forced on a researcher is generally linked to one of these motives. Nothing is deadlier to the spirit of discovery.

Fortunately, the world is filled with curious people. As I see it, any robust research pursued with genuine vigour and the spirit of discovery has value. The immediate values and the long-term values of any given research programme change and shift with time.

The research dean at a university once told me that a study of faculty publishing revealed that it takes nearly one thousand hours of work to develop a research article from first conception to final publication. Clearly, it is hard to pay for the work this requires. This leaves curiosity and passion as the most reliable motives for research.

10 From research into practice

When we began, I promised to address a number of issues. We have considered the nature of design and reflected on how the

nature of design involves certain kinds of knowledge. We have examined the sources of knowledge. We have considered research as a source of knowledge, and we have considered research in relation to other sources of knowledge. This has taken us a long way.

Developing a sound line of reasoning takes time. The time it takes can often lead to surprisingly swift conclusions. To fit these thoughts in an hour, with time for dialogue, I'm going to consider the last two questions in summary form. The first involves how we create design knowledge through research. The second asks how new knowledge move from research into practice.

Creating design knowledge rests open all the sources we've considered here. Practical experience is only one of these. Practice alone cannot create new knowledge. Not even reflective practice will generate new knowledge in significant measure. The interplay of experience and reflection, inquiry and theorizing generates knowledge. One task of research is examining the ideas that arise from the interplay of these different forms of knowledge. Research then helps to establish those forms of knowledge that offer the greatest potential for further development.

This new knowledge moves into practice in hundreds of ways. The field of innovation studies examines the ways that new ideas are adopted in practice. [See endnote 2].

Here, I'm going to cheat a little and offer a very brief account of how this knowledge moves from research into practice. Fortunately, I also promise not to answer all these questions, so ending with a summation will keep my promise and meet my guarantee to be done on time.

In a new field, the greatest need is to build a body of research – and to train a rich network of researchers and research-oriented practitioners able to use the knowledge won in research as a foundation for practice. Research becomes the foundation of practice in many ways. One is the foundation of concrete results. The other, perhaps even more important, is in the development of critical thinking and good mental habits. These are the reasons that argue for the design science approach to design education (Friedman 1997).

Concrete research results become visible to practitioners in a myriad of ways. Journal results, conferences, corridor talk among colleagues, knowledge transfer in shared projects, Internet discussion groups. The important issue is that a field must grow large enough and rich enough to shape results and circulate them. As this happens, the disciplinary basis of the larger field also grows richer. This leads to a virtuous cycle of basic results that flow up toward applied research and to clinical applications. At every stage, knowledge, experience and questions move in both directions.

The goal is a full knowledge creation cycle that builds the field and all that practise in it. Practice tends to embody knowledge. Research tends to articulate knowledge. The knowledge creation cycle generates new knowledge through theorizing and reflection both.

I'm going to end by proposing the kinds of research that we need to build our field and the kinds of research that we must undertake to build the discipline that supports the field we build.

Not long ago, Tore Kristensen (1999: unpaged) raised an issue of stunning importance for design research in addressing the notion of a progressive research programme. The minute I heard him propose the idea, I realized that this concept was so evident to those of us who work in other fields that we had somehow overlooked the fact that no similar notion had yet been proposed in the field of design.

What is a progressive research programme? Drawing on Kristensen (1999: unpaged), I have identified eight characteristics of a progressive research program. These are:

1 building a body of generalized knowledge,
2 improving problem solving capacity,
3 generalizing knowledge into new areas,
4 identifying value creation and cost effects,
5 explaining differences in design strategies

and their risks or benefits,
6 learning on the individual level,
7 collective learning,
8 meta-learning.

Four areas of design research must be considered in creating the foundation of progressive research programmes within and across the fields of design:
1 Philosophy and theory of design
2 Research methods and research practices
3 Design education
4 Design practice.

Each field of concern involves a range of concerns. (See Figure 3)

In 1900, David Hilbert gave a famous speech in which he outlined a progressive research programme for mathematical knowledge. In the years after Hilbert proposed a progressive research programme, mathematicians solved fundamental theoretical and philosophical problems. They contributed to rich developments in physics and the natural sciences. They even shaped applications that make it possible for all of us to live a better daily life. What I hope for in design research is many streams of work leading to new andimportant kinds of knowledge.

These will serve the field of practice in manyways. Research serves the field through

Philosophy and theory of design	Research methods and research practices	Design education	Design practice
Philosophy of design Ontology of design Epistemology of design Philosophy of design science Theory construction Knowledge creation	**Research methods** Research issues exploration Progressive research programs Development from research to practice	**Philosophy of design education** Education based on research Education oriented to practice **Rethinking undergraduate education** Undergraduate focus on intellectual skills for knowledge economy Undergraduate focus on practice skills for professional training Undergraduate focus on foundations for professional development **Rethinking professional degrees** Professional degrees oriented around intellectual skills Professional degrees oriented around practical skills Professional degrees oriented around professional development **Research education** Undergraduate and professional background for research education Research master's degrees Doctoral education Postgraduate training **Continuing education** Lifelong learning Partnership with design firms Partnership with professional associations Partnership with industry Partnership with govt	**Comprehensive practice** **Profound knowledge** **Practice linked to solid foundations in education and research** **Professional develop-ment lifelong learning**

Figure 3 A progressive research program for design knowledge

generating direct, concrete applications. Research serves the field by solving problems that arise from the field itself. Research serves the field by considering basic questions and issues that will help to shape disciplinary inquiry and fields of practice both. Research serves the field by opening inquiry into basic questions that we haven't yet begun to ask.

All of these are part of the knowledge creation cycle. The important moment has come in which research joins practice to build a community of design inquiry suited to the challenges and demands of a knowledge economy.

Thank you.

Endnotes

(1)

A consideration of design knowledge is not the forum for a detailed discussion of these issues. Nevertheless, design knowledge must be considered against the background of the large cultural, social and economic trends these issues define. Those who wish a richer picture of my views on the social and cultural transformations of the past century will find a deeper discussion elsewhere (Friedman 1998; Friedman and Olaisen 1999a). Those who wish to go deeper still will find a massive body of books and articles. Among these, a few stand out, framing the issues of the new society in a comprehensive philosophical, scientific or socioeconomic frame (f.ex., Bell 1976; Berg et al. 2000; Borgmann 1984, 1992; Castells 1996a, 1996b, 1996c; Castells and Hall 1994; Drucker 1990, 1998; Flichy 1991, 1995; Innis 1950, 1951, 1995a, 1995b; Machlup 1962, 1979, 1983; Mitchell 1995; Nye and Owens 1996; Olaisen et al. 1996; Paik 1974; Sassen 1991, 1996)

(2)

Innovation studies comprise a broad field of inquiry (Damanpour 1991). Authors distinguish between the "diffusion" and "adoption" of innovations (Kimberly 1981: 85) as well as between studies of "innovating" and "innovativeness" (Van de Ven and Rogers 1988: 636). The primary purpose of most innovation studies has been to demonstrate the existence of empirically distinguishable dimensions of innovation and identify their associated determinants (Damanpour 1991).

Much of the work on innovation has been in the context of organization theory. Given the fact that design is generally an organizational process, these studies can readily be adapted to understand how design research can lead to improved practice in the context of design firms and the industries they serve. While some innovation studies examine organizations well beyond the scope or scale of most design firms, the ideas they develop can be fruitfully pursed in the context of design.

The propensity to innovate is a stable characteristic of organizations over time (Miles and Snow 1978; Miller and Friesen 1982; Mintzberg 1973). It depends on organizational size, structure and leadership (Burns and Stalker 1966; Daft 1982; Damanpour 1992; Damanpour and Evan 1984; Hage and Dewar 1973; Kimberly and Evanisko 1981; Lawrence and Lorsh 1967; Mohr 1969; Tushman and Romanelli 1985; Wilson 1966).

There are several kinds of innovation. These include technological innovation and administrative innovation (Daft 1978; Kimberly and Evanisko 1981; Damanpour 1987). Administrative and technical innovations do not relate to the same predictor variables (Aiken, Bacharach and French 1981; Evan and Black 1967; Kimberly and Evanisko 1981). In the "dual-core-model" of organizational innovation, low professionalism, high formalization, and high centralization facilitate administrative innovation. Inverse conditions facilitate technical innovation (Daft 1978: 206). The "ambidextrous model" of innovation suggests that high structural complexity, low formalization, and low centralization facilitate the initiation of innovations while inverse conditions facilitates their implementation (Duncan 1976: 179).

There are a number of distinctions to be made concerning the quality and character of innovation. Innovation can be either radical or incremental (Dewar and Dutton 1986;

Ettlie, Bridges, and O'Keefe 1984; Nord and Tucker 1987). In addition, there are important differences the govern the initiation and implementation stages of adopting of innovation (Marino 1982; Zmud 1982). There are also different organizational levels involved in innovation (Aiken, Bacharach, and French 1981).

Some investigators have found that substandard performance causes dysfunctional behaviour and diminished innovation (Caldwell and O'Reilly 1982; Cameron, Kim and Whetten 1987; Hall 1976; Manns and March 1978; McKinley 1987; Smart and Vertinsky 1977; Starbuck, Greve and Hedberg 1978; Staw, Sanadelands and Dutton 1981).

Others argue that poor performance is actually necessary as a catalyst of the search for new practices in an organization (Argyris and Schon 1978; Bowman 1982; Chandler 1962; Cyert and March 1963; Meyer 1982; McKinley 1987; Singh 1986; Wilson 1966;).

Organizations tend to act inconsistently. They can lead their industries with innovative practices in one period, while lagging behind their peers as late-adopters at other times (Mansfield 1968).

An alternative view claims that the propensity to innovate will vary over time, following a company's performance level (Bolton 1993; Mansfield 1968).

A growing body of literature (Tushman and Romanelli 1985; Tushman and Anderson 1986) suggests that organizations evolve through convergent periods punctuated by reorientation or major innovations which reconfigure the organization's path into the next lengthy period of incremental adaptation and adjustment (Miller and Friesen 1984).

Contingency theorists and strategy researchers also provide affirmative theoretical supportive for a positive relationship between substandard organizational performance and innovation. One stream of contingency research asserts that changing environments may lead to declining performance if prompt realignment of the fit between strategy and structure fails to occur (Burns and Stalker 1966; Chandler 1962; Lawrence and Lorsch 1969). Firms experiencing declining performance may therefore change strategies (Miles and Cameron 1982) and ultimately develop organizational structures to respond more effectively to new environmental contingencies. Indeed, one might argue that the increase in "hybrid" organizations, strategic alliances and other novel cooperative arrangements between firms (Borys and Jemison 1989; Powell 1987) constitutes widespread organizational innovation in response to declining performance stemming from environmental change.

There is now a growing body of overview literature in the field, including conceptual articles and reviews Daft 1982; Damanpour 1988; : Kimberly 1981; Tornatzky and Klein 1982; Van de Ven 1986; Wolfe 1994.

Together with two colleagues (Friedman, Djupvik and Blindheim 1995) I reviewed these issues at greater length in relation to professional education and in relation to the specific issues involved in innovation as a research field.

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