Claims of Knowledge in Design

James Chia-Ming Liu

A thesis submitted to the Carnegie Mellon University School of Design for the degree of Master of Design in Interaction Design.

James Chia-Ming Liu, Author

Dr. Suguru Ishizaki, Advisor
Associate Professor of Rhetoric & Communication Design
Carnegie Mellon University

PREFACE

This thesis is the culmination of a two year journey equivalent to sailing across the pacific on a very leaky ship. Through heavy swells and strong winds, I have to first thank the heroic Captain Suguru Ishizaki for guiding this ship safely to shore with minimal loss of life. I am humbled to have received your attention and mentorship; through the bleakest of times, our thought-provoking conversations made me believe that land was indeed within reach. To the other officers on the ship, Kristin Hughes, John Zimmerman, and Dan Boyarski, your encouragement and stewardship kept me intellectually stimulated and emotionally balanced through heavy bouts of sea sickness.

My fellow sailors, especially Sarah Phares and Yash Vora, I am honored to have served together on this ship bailing out water and fighting off sea-monsters. Even though most of us got scurvy, I will remember our time together with great joy and terror. Years from now, I know we will still share drinks and reminisce about our grand adventure.

I want to thank my parents, Joseph and Sharon Liu for supporting me in every way. I love them for being tremendously proud of me even if they *still* don't know what I do. To my lovely-best-gene-taking sister Lindia, thank you for taking care of our parents so I didn't have to.

Finally, to Christopher and Jenny Liu-Geihsler, you two stowaways always rekindle by belief in humanity.

ABSTRACT

The discipline of design, while a relatively young field in terms of academic scholarship, has gained a surprising amount of traction in many professional and academic communities. This growing attention to a design-oriented approach parallels the emergence of new fields of interest such as Experience Design, Service Design, and even Organizational Design. Pushing the boundaries of their arts and craft training, designers now assert the ability to address a broader set of design problems beyond their disciplinary tradition.

Underlying this transformation of professional practice is the recognition and promise of Design Thinking. This popular notion has been hailed as the integrative "design sensibility" that not only permeates all of design, but is also a competency that allows designers to approach a wide range of challenges. Yet, at the same time, the discourse around Design Thinking not only belies its complexity and history, but also overlooks many questions that concern the traditional disciplines of design. Simply put, the discussion revolves around what Design Thinking *is* rather than on how Design Thinking *develops*. If indeed designers have the ability to address complex challenges that lie outside of their traditional domains, what knowledge should designers possess? To understand what it means to *think* like a designer, one must first understand what is it that designers *know*.

In order to answer this question, this thesis examines previous studies on design epistemology—an area identified by Nigel Cross as one of the three topics of study necessary in establishing an "interdisciplinary discipline of design." I being this thesis by reviewing the progress made towards understanding design knowledge and abilities since the design method movement in the last half of the 20th century. I then survey recent development in the models of design research to provide a perspective from the current conversation on disciplinary boundaries and purposes. Finally, I conclude this essay by proposing a framework that demystifies the notion of *discipline-independent* and *discipline-specific* design abilities.

Claims of Knowledge in Design

by James Chia-Ming Liu

TABLE OF CONTENTS

INTRODUCTION

The discipline of design, while a relatively young field in terms of academic scholarship, has gained a surprising amount of traction in many professional and academic communities. This growing attention to a design-oriented approach parallels the emergence of new fields of interest such as Experience Design, Service Design, and even Organizational Design (Boland and Collopy 2004). Pushing the boundaries of their arts and craft training, designers now assert the ability to address a broader set of design problems beyond their disciplinary tradition.

Underlying—and contributing to—this transformation of professional practice is the recognition and promise of Design Thinking. Tim Brown of IDEO is often credited with the rise of interest in the business world over Design Thinking; Brown defines Design Thinking as "the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity" (2008, 86). This certainly was not the first time Design Thinking had been framed in the context of business. As early as 1986, Kotler and Rath saw the potential of applying design as a "process of seeking to optimize consumer satisfaction and company profitability through the creative use of major design elements in connection with products, environment, information, and corporate identities" (1984, 17). While both Brown and Kotler's emphasize the process of design, other definitions of Design Thinking emphasize the cognitive differences exhibited by designers. Along with ideas of "integrative thinking" and "hybrid thinking", Design Thinking has been offered as a challenge and alternative to the dominant rationalized thinking in the business world (Martin 2009). This notion is best captured by Dunne and Martin's definition: Design Thinking "combines the generation of new ideas with their analysis and an evaluation of how they apply generally. A designer uses abduction to generate an idea or a number of ideas, deduction to follow these ideas to their logical consequences and predict their outcomes, testing of the ideas in practice, and induction to generalize from the results" (2006, 518). This emphasis shows design not as a creative endeavor reserved for the talented few, but as systematic and rigorous process of thinking that can be beneficial for those outside the creative arts.

While there have been and continue to be, numerous attempts, the definition of Design Thinking is probably best left unsaid; in many ways,

the ambiguity of Design Thinking also gives it its strength, "allowing it to be the right thing at the right time" (Zimmerman, Forlizzi and Evenson 2007, 45). This recent attention, nonetheless, illustrates the sentiment that a designer's way of thinking or understanding can serve practical purposes in arenas and disciplines outside of the traditional arts and craft's heritage of design. Indeed, this idea reflects a long held belief that the wide range of "designerly" activities, from Service Design, Human-Computer-Interaction, Industrial Design, Communication Design, and Architecture, all share a common source of knowledge. A unifying discipline of design has been a widely studied and discussed topic ever since Herb Simon's *The Sciences of the Artificial* proposed a common ground between the sciences, arts, and technology. Simon's oft cited definition of design provided a large umbrella for the discipline: "Everyone designs who devises courses of action aimed at changing existing situations into preferred one" (1969, 111). A more contemporary definition of Design echoes much of Simon's outlook: "Design is the human power of conceiving, planning, and making products that serve human beings in the accomplishment of their individual and collective purposes" (Buchanan 2001, 191). Given these two definitions of design, it is easy to understand why many have hailed design as transcending disciplinary boundaries (Blevis and Stolterman 2009). But with the discipline's academic youth, it remains relatively unanswered what type of "transcendent" or *discipline-independent* design knowledge or abilities exists.

This paper is a response to the growing discussion around Design Thinking that focuses on what it *is* rather than on how it *develops*. As the popularity of design opens up new arenas and domains for the practicing designer, a better understanding of such discipline-independent design abilities becomes all the more necessary. From as early as the methods movement—which initially marked a systematic approach towards studying design—design academics and practitioners have explored and examined design epistemology from many different perspectives (Cross 2007). This thesis will examine the progress made towards understanding design knowledge and abilities. This paper will then survey different integrative models of design research to point out the current conversation on disciplinary boundaries and purposes. Finally, the conclusion suggests a framework to understand and demystify the notion of *discipline-independent* and *discipline-specific* design abilities.

Nigel Cross, in trying to establish a Science of Design—with *science* interpreted in the broadest sense as a systematic knowledge-base—determines three topics of investigation for the discipline of design: 1) Design Phenomenology, the study of design artifacts, 2) Design Praxiology, the study of design process, and 3) Design Epistemology, the study of how designers know (2007, 101). While all three topics are studied extensively, the study of Design Epistemology has largely motivated the development towards a unified design discipline; this section aims to trace and clarify the progress made. Epistemology is defined in philosophy as the study of knowledge and justified belief (Steup 2005); topics of epistemology include questions of *what is knowledge*, *how is knowledge acquired*, *what do people know*, and *how do we know we know* (Wikipedia contributors n.d.). Even though the study of design knowledge can be traced back to Greeks and the separation of epistêmê and technê, focus will be placed on writings after the industrial revolution where the separation of design from manufacturing best reflects contemporary design practice.

Early Progress

Architecture has provided the best and most documented history of knowledge for the study of design. Starting in the early 20th century, designers have sought to create theories and knowledge in order to provide justifications for their work. Contemporary Design theory can still trace a large part of its heritage to the Modernist movement. The Modernist movement in architectural theory started as a response that "led to the replacement of a style based on classical orders...and on the rejection of decorations for its own sake" (Lang 1987). Architects such as Le Corbusier and Walter Groupius promoted ideologies such as *Functionalism* and other *aesthetic philosophies* that showed a detachment and misguided understanding of the person-environment relationship. Most of such ideologies point to the power of the physical environment in shaping human behavior—also known as *architectural determinism*. There was a gross misunderstanding of the differences between causality and correlation that led to unsubstantiated assumptions—"community facilities are said to create communities, parks to reduce vandalism, architectural unity to create social unity, architectural magnificence to lift spirits" (Lang 1987). Even in post-modern ideology, architectural theories and practices remain heavily influenced by these Modernists schools of

thought—inheriting the ideologies from the Futurists of Italy, the De Stijl group of Holland, the Cubists of France, the Rationalist and Constructivist in the Soviet Union, and the Bauhaus in Germany (Lang 1987).

Design Methods Movement

These early attempts at creating theories of design worked primarily as normative theories that prescribed action rather than positive theories that constitute declarative knowledge. It was not until after World War II when "the new techniques that had been used in the design and development of arms and wartime equipment, and the methods and techniques used in developing many new inventions" revolutionized engineering and the sciences did designers begin to take note (Bayazit 2004, 17). Contemporary scholars coined this as the Design Methods Movements, and this shift in ideology marked the first serious attempt at creating declarative knowledge for design.

Spurred on by the influences of systems theories, designers sought to pioneer scientific approaches to design. The period from the early 1960's to the early 1970's created a body of knowledge that is now often referred to as "First Generation" Design Methods (Rittel and Webber 1973). Showing the influence of operational research, theories from this time focused primarily on the nature of the design process and sought to hierarchically break down complex design problems. Theories offered by Christopher Alexander with *Notes on the Synthesis of Form*, John Chris Jones with *A Method for Systematic Design*, and L. Bruce Archer with *Systematic Methods for Designers* all sought to provide systematic methods grounded in positivist theories such as information theory and critical path analysis (Bayazit 2004, 18-20). Herbert Simon's *The Sciences of the Artificial* (1969) was also introduced during this period and aimed at creating a new discipline of study—the man-made artificial world—grounded in a scientific approach . It is important to note that while "first generation" methods were wholly dismissed even by the proponents themselves—as seen in Alexander's introductory apology in later editions of *Notes on the Synthesis of Form*—these methods focused on the nature of analyzing and synthesizing the design problem. The essential component of the "creative leap" and designer intuition was never replaced completely by systematic methods; instead many of these early methods sought to supplement the designer's mind rather than replace it.

By the mid 1970s, there was a growing reaction against the first generation systematic methods; in what is considered now to be "second generation" design methods, theories began to form around the nature of the design problem rather than the design method (Rittel and Webber 1973).

The failures of the more reductionist approach led to many designers believing that if "the nature and structure of design problems are understood, then methods for tackling them may be developed with more certainty of success" (Cross 1984). Both Simon and Rittel focused on the "ill-structured" or "wicked" problems that do not afford straightforward hierarchical decomposition. While Rittel argued that ill-structured problems could only be approached through an argumentative process, Simon argued that there are no clear boundaries between "ill-structured" and "well-structured problem" (Simon 1973). Simon further argued that ill-structured problems become well-structured when the knowledge set of the problem solver is brought to bear on the situation. He concluded that the differences in the nature of problems for the general problem-solver lay only in the body of knowledge he or she has grasp of; this particular claim calls the mind the notion of the Design Thinker as a general problem solver of indeterminate problems. However, what particular "body of knowledge" the general problem-solving designer has is largely unclear. In following this, the discourse shifted away from the external act of designing and towards the individual thinking and behavior of a designer.

Design Cognition: A type of thinking

Similar to the methods movement, theories on how a designer thinks tend to fall within certain camps and ideologies. From the Behaviorist's stimulus-driven approach of trial and error, the Gestalt school's pattern recognition, to the Cognitive Science's processes of perception and conscious thought, researchers from different fields have tried to investigate the nature of how people think and act (Lawson 2006). Regardless of the different perspectives taken on the nature of thinking—and with respect to a certain amount of generalizing—the consensus on the dual nature of design thinking emerges. Lawson points out that two factors play the most important role for designers in their style of thinking—reasoning and imagining:

> Reasoning is considered purposive and directed towards a particular conclusion. This category is usually held to include logic, problem-solving and concept formation. When "imagining", on the other hand, the individual is said to draw from his or her own experience, combining material in a relatively unstructured and perhaps aimless way.

But the distinction is not so clear and a designer's thinking falls mostly on a spectrum between the two. Still this dualism of thinking has been a constant theme since the early Behaviorists and has been called different ways: directed vs. undirected, analytical vs. synthetic, pre-hypothesis vs. post-hypothesis and convergent vs. divergent. As noted earlier, Martin's

more nuanced definition of Design Thinking as a counterpart to the dominant analytical modes of thinking recalls many aspects of design cognition.

The creative aspect of cognition tends to allow designers to "juggle" many things at once; Designers seem to "cope with the lack of resolution [of the design process] in two main ways: by the generation of alternatives and by using 'parallel lines of thought" (Lawson 2006). However, other scholars have challenged this notion of parallel thought; instead the dialog between designer and the situation takes place through a process of "selective inattention," where multiple lines of argument follow each other in serial (Rowe 1987, 105-106). Studies into the problem-solving nature of designers illustrate that while scientists try to uncover the underlying structure or truth of a problem, designers tend to try a number of valid solutions until an acceptable one fits (Lawson 1979). This leads credence to the argument that "Designing is essentially a way of looking at a problem; not exclusive to a type of problem" (Cross 1984).

Designer's Perspective: A way of looking

Simon argues that all problems are inherently ill-structured until transformed into a well-structured one by an individual's body-of-knowledge (1973). This suggests that each discipline of design—as well as any other discipline—equips its practitioners with a set of tools or knowledge to address a certain set of problems. Indeed, it is rather unlikely that Communication Designers will have much to contribute to the design of a high-rise building. Nevertheless, while the body-of-knowledge and problem space may have disciplinary differences, the study on designer cognition has shown there to be general characteristics exhibited by all designers—mainly the perspective a designer takes in tackling a problem. The challenge ahead is to understand how this design *way of looking* is related to a discipline-specific body-of-knowledge.

Rather than seeing a body-of-knowledge as static and prescriptive, scholars have proposed the notion of *pre-structures* to address the dynamic and fluid nature of knowledge (Hillier, Musgrove and O'Sullivan 1984). Such *pre-structures* consist of the initial understandings, knowledge, biases, and values that inevitably shade the perspective of an individual. Though similar in concept to a body-of-knowledge, the distinction is that *pre-structures* becomes more sharply defined and better formed as the problem-solver gains knowledge through the resolution of the problem. With this interpretation, design as a *different way of looking* at problems becomes much more significant. Rather than falling into the trap of generating knowledge as static normative theories, positive theories, or

aesthetic philosophies as early design scholars have (Lang 1987), this interpretation allows a process of contextualized knowledge creation; the solution-finding nature of design cognition provides the opportunity to generate knowledge as well as fluidity to adapt to the specific problem at hand. However, this notion of *pre-structures* and *perspective* shifts the focus back towards the act of design as an individual process. Yet instead of returning to the romantic vision of the creative genius (Fallman 2003), a more pragmatic account has evolved.

Design Process: An act of meaning making

An integral aspect of design knowledge comes through the shaping of knowledge as one undergoes the process of designing and how such knowledge in turn affects the designer's interpretation of the situation. Panagiotis Louridas uses Levi-Strauss' metaphor of "The Bricoleur" in describing the designer: "The bricoleur's dialog with his materials and his word continues throughout the process, since his decisions to use something for a specific purpose have consequences that he cannot foresee...the results of these interactions are never what he expects, and he must respond to them" (Louridas 1999, 519). Similar to this concept, Schön describes knowledge in design as a process of reflection-in-action, a designer "shapes the situation, in accordance with his initial understanding of it, the situation 'talks back,' and he responds to the situation's back-talk" (Schön 1983, 79). The ability and knowledge found in the practice of reflective-action is not limited to the designer, as "scientists and engineers learn to model unfamiliar problems on familiar ones and build new theory by reflecting on perceived but as yet unarticulated similarities" (Schön 1983, 203). With this perspective, knowledge is gained through a process of interpretation and meaning making.

Regardless of its basis in sciences or in design, a hermeneutic problem solving process requires the same initial conjecture—or problem framing—before applying a body of knowledge to bear on the situation (Schön 1983). While indeed such framing will and must necessarily change, framing for both the scientist and the designer surface not from confronting the current problem but rather from the "pre-existing cognitive capability—knowledge of the instrumental sets, solution types, and informal codes, and occasionally from right outside—an analogy perhaps, or a metaphor, or simply what is called inspiration" (Hillier, Musgrove and O'Sullivan 1984).

To a certain extend, the discussion arrived back at where it began. The understanding of design's *pre-structures* is foundational to the understanding of design epistemology as a discipline that sits beyond its arts and crafts heritage. What has become abundantly clear, however, is

that a technical rationale for design—mainly in attempting to establish a scientific discipline of design—has not produced fruitful outcomes. Instead, as suggested by the study of design cognition, the solution-finding and synthetic nature of design has driven the foundational arguments for an integrative discipline of design.

Design as part of the human experience

In *The Sciences of the Artificial*, Simon called for design to become that of a liberal art: "Proper study of mankind is the science of design, not only as a professional component of technical education but as a core discipline for every liberally educated man" (1969, 138). While Simon grounds his study of mankind in the artificial science (study of artificial intelligence), his sentiment remains influential to the design community. This new liberal art mirrors what Nigel Cross calls a *third culture of human knowledge* that seeks to understand the "application of scientific and other organized knowledge to practical tasks" (2007, 18). For Cross, this culture of design can also be considered the culture of technology—material outcomes of design making. In fact, the argument for placing design as the integrative discipline revolves around the fundamental relationship of technology between the natural world and human experience. As the culture of science becomes ever more specialized, the advancements of knowledge created in such circles become further detached from common matters of daily life; "without integrative disciplines of understanding, communication, and action, there is little hope of sensibly extending knowledge beyond the library or laboratory in order to serve the purpose of enriching human life" (Buchanan 1992b, 6). Buchanan also places design as a liberal art of technological culture; drawing from McKeon and Dewey, Buchanan sees technology not as mere products but as a *discipline of systematic thinking* (1992b, 19) that is "informed by knowledge of the physical and biological sciences, the social sciences, and the fine arts, but not reducible to any of these" (1992a, 3). When viewed in this context, Design becomes the obvious candidate for "exploring the concrete integrations of knowledge that will combine theory with practice for new productive purposes" (Buchanan 1992a, 6). By perceiving design as a liberal art, Buchanan does not discount the challenge of discovering a better understanding of design thinking. In fact, he states quite plainly:

> The challenge is to gain a deeper understanding of design thinking so that more cooperation and mutual benefit is possible between those who apply design thinking to remarkably different problems and subject matters. This will help to make the practical exploration of design, particularly in the arts of production, more intelligent and meaningful (1992b, 8)

Buchanan also offers the *doctrine of placements* (1992b11-14) as the crucial tool of invention for the integrative design thinker. As an example of *pre-structures*, Buchanan identifies signs, things, places, and thoughts—referred elsewhere as the four orders-of-design—as examples of placements that allow the designer to invent solutions through conceptual repositioning: "by using placements to discover or invent a working hypothesis, the designer establishes a principle of relevance for knowledge from the arts and sciences, determining how such knowledge may be useful to design thinking in a particular circumstance without immediately reducing design to one or another of these disciplines" (1992b, 18). The doctrine of placement and the four orders of design can be considered one of the few knowledge contributions to the epistemology of an integrated discipline of design.

Lastly, it is important to note that Buchanan makes a clear distinction between design thinking and the activity of production and making. He argues that a complete product reduces and abstracts the kind of activities and thinking that went into inventing the product; instead, design thinking "is a synthetic activity related to indeterminacy, not an activity of making what is undetermined in natural laws more determinate in artifacts" (1992b, 18). This separation is important as it represents a clear disassociation of design away from its arts and craft tradition. Though promising, this separation is unfortunately also problematic as a result of its loss of a distinct body-of-knowledge to ground a new integrative discipline.

As the literature review has shown, the short history in the study of Design Epistemology has succeeded—to a great extent—in arguing for an integrative design discipline that differs from traditional and specialized epistemologies. However, contemporary scholars in design are now faced with the problem of establishing a model for this integrative discipline. It is generally agreed upon in the design community that in order for an integrative field of design to develop, a deeper understanding of the shared knowledge of design is crucial in order to push against the fracturing of design knowledge into specialized domains. Indeed the field is proceeding in a "paradoxical task of creating an interdisciplinary discipline" (Cross 2007, 124). Accordingly, as the fields of design continue to struggle in freeing design from the ideology of science, different disciplinary models have emerged. The models of Design Research provide an interesting perspective on the future direction and possibilities for the discipline. The following section provides an overview on the current discourse surrounding models for design research—each with a different aim and focus on developing knowledge in design.

Models of Design Research

In building this discipline of design, research plays an integral role. As mentioned earlier, Nigel Cross (2007) provided a framework to guide the development of design research: 1) Design Phenomenology, 2) Design Praxiology, and 3) Design Epistemology . This paper's focus on knowledge in design, while framed in Design Epistemology, cannot be simply contained only in aspects of how designers know; theories of knowledge in design clearly involves both studies of design artifacts as well as process. The discussion on Design Epistemology is mainly due to the breadth of knowledge already established from research in Design Phenomenology (products) and Praxiology (process). Studies in design semantics and semiotics make up a long tradition of research in the traditional fields of communication and industrial design (Krippendorff 2006; Hall 2007). The methods movement, while creating theories of knowledge in design, contributes to the study of design methodology and process. Furthermore, developments in human-centered-design methodology draw deep roots from the Scandinavian participatory design movement and HCI (Muller and Kuhn 1993). Models of design research can be placed into two categories: research in interdisciplinary disciplines such as HCI, where

design contributes to an already established tradition of research, and integrative disciplines where design itself is the focus of research.

Design Research in Interdisciplinary Fields

The field of Human Computer Interaction (HCI) offers an example of the application of design into traditional notions of research. Design has become what has been called the "Third-Paradigm" of HCI, building upon the traditional scientific ideologies of cognition and information theory (Harrison, Sengers and Tatar 2006). Accordingly, interaction designers working in HCI have begun to offer models of approaching *research through design* (Zimmerman, Forlizzi and Evenson 2007).

Zimmerman et al. proposes a model of design research that focuses on creating knowledge through objects (Phenomenology). The model of research applies the strength of the design practitioners at "addressing under-constrained problems" while removing commercial constraints, in essence having design researchers making "*right*" instead of "*commercially successful*" things (Zimmerman, Forlizzi and Evenson 2007). Continuing this discussion, Zimmerman and Forlizzi (2007) points out that design objects can serve as "a specific instantiation of a model—a theory—linking the current state to the proposed, preferred state" . Furthermore, design theory in the form of "extensible constructs" and knowledge "in the form of processes, design methods, and empirical evaluations" are also results of *research through design* in HCI (Zimmerman, Forlizzi and Evenson 2007).

The adoption of design in the field of business and organization management also holds potential for further development in design research (Boland and Collopy 2004).

Design Research in the Discipline of Design

In the short history of establishing an integrative discipline of design, several models have been put forward in addition to Cross' three categories of design research. Richard Buchanan offers the model of *clinical*, *applied*, and *basic* to address the perspectives of design problems researchers can take (2001, 17-19). The clinical perspective uses the case study method as a basis for learning—a practice common in design education as well as other disciplines. Applied research on the other hand aims to create knowledge pertaining to a set of problems or class of problems. Finally basic research is "directed towards fundamental problems in understanding the principles—and sometimes the first principles—which govern and explain phenomena" (Buchanan 2001). This three tiered approach aims to give design researchers a language and framework to identify their scope of

design work; however, the classification does little to prescribe how one approaches basic research to create first principles in design.

Daniel Fallman (2003) presented a model of design research activity at the Umeå Institute of Design as a triangle of design practice, design studies, and design exploration . These three activities represent a separation in perspective; design practice focuses on the development of situated *engaged knowledge*, design studies focus on the creating *cumulative* knowledge aimed at describing and understanding design, and design exploration seeks to "provoke, criticize, and experiments" (Fallman 2008, 8). Furthermore, Fallman emphasizes the importance of activity, transfer, and exploration of knowledge between the three perspectives.

Recently, the notion of *Transdisciplinarity* has gained popularity in the field of design research. Instead of viewing design as interdisciplinary, where research is integrated from a "collection of methods informed by or in the service of combined bodies of knowledge", the transdisciplinarity approach focuses not "on particular bodies of knowledge, but rather focuses on a broader goal" (Blevis and Stolterman 2009, 49). Design research, as seen in a transdisciplinarity sense, focuses on solving problems first and creating knowledge second. Institutions such as RMIT Design Research Institute subscribe to a model of transdisciplinarity research.

Design Research Frameworks

If the recent developments of design research are any indication, the development of design discipline is alive and healthy. Research models from HCI as well as Transdisciplinarity focus less on creating a deeper understanding of design epistemology, yet when all models are taken as a whole, the aims of knowledge creation covers Cross' three levels of design research. However, a preferred research model has yet to achieve consensus in the design community. Falman's model comes perhaps the closest in capturing an intuitive and holistic relationship that bridges the activities of design research. As the discipline of design moves forward, it is important to remember Buchanan's warning:

> Some see no need for design research, and some see in the problems of design the need for research that is modeled on the natural sciences or the behavioral and social sciences as we have known them in the past and perhaps as they are adjusting to the present. But others see in the problems of design the need for new kinds of research for which there may not be entirely useful models in the past—the possibility of a new kind of knowledge, design knowledge, for which we have no immediate precedents (Buchanan 2001, 7).

As the literature reviews on knowledge creation in design have shown, the short history of design has generated a great deal of understanding in design cognition, behavior, perspective, and theories that, when taken together, constitute an epistemology of design. Furthermore, as the review on models of design research suggested and the new arenas of design support, there is still no clear front-runner in establishing a discipline of design separate from the arts and crafts tradition. The emergence of new fields of design in Service Design, Experience Design, and Strategy Design is the direct result of the strides and progress made at establishing design as transcending its traditional arts and crafts tradition. Yet due to the immaturity of these fields, much of the respective discourse focuses on new domains of problems rather than carrying on Nigel Cross' call for an interdisciplinary discipline of design.

What this exploration has revealed is that while knowledge is in abundance, there is a need to clarify, categorize, and identify what has been established and agreed upon. While design as an epistemology has been identified, little has been said about how such design abilities develop. This paper will now turn to a more recent revision of Bloom's Taxonomy (Anderson, Krathwohl and Bloom 2001) as a framework in order to gain a better understanding of the developmental aspects of design knowledge. This widely accepted educational tool provides the necessary language and established criterion for this discussion. This section will present a framework using Bloom's Taxonomy as a way to understand design knowledge and abilities as the discipline of design moves away from its roots in the arts and crafts tradition. The framework as presented is an incomplete model that aims at comparing abilities that constitute *discipline-specific* and *discipline-independent* design. The conclusion will outline some opportunities that lie in using the framework.

Bloom's Taxonomy

Since the 1950's Benjamin Bloom's identification of three domains of human development—better known as Bloom's Taxonomy—has remained a popular and relatively stable educational taxonomy (1956). Bloom identified three domains: *psychomotor*, *cognitive*, and *affective*. The psychomotor domain includes the "manipulative or motor-skill" aspects of human abilities. The cognitive domain "includes those objectives which

deal with the recall or recognition of knowledge." Finally, the affective domain "includes objectives which describe changes in interest, attitudes, and values."

While the cognitive domain has historically received the most interest and study, the accompanying domains of psychomotor and affective have been seen as closer related and overlapping in newer revisions of Bloom's Taxonomy. For the purposes of this framework, a revision of Bloom's cognitive domain will be used that includes a second dimension that helps disambiguate the relationship of knowledge and cognition (Anderson, Krathwohl and Bloom 2001). The knowledge dimensions are organized into Factual Knowledge, Conceptual Knowledge, Procedural Knowledge, and Metacognitive Knowledge.

While Bloom's taxonomy has been traditionally used to describe educational development and achievement, this framework will not be used to describe the scales of achievement in design abilities—such as the information recall or evaluation. Instead, the taxonomy will be used as a means to break apart and categorize design abilities into the domains of affective, pscychomotor, and cognitive. Furthermore, in following the intentions of this paper to better understand Design Thinking, a distinction will be made between discipline-independent and discipline-specific design abilities as opposite poles of a spectrum. For the sake of simplicity, the discipline of Visual Design will be used to illustrate discipline-specific abilities.

Psychomotor Domain

The Psychomotor Domain, as mentioned earlier, is most often considered to include physical manipulation, coordination, and use of other motor-skills. While Bloom's original study never provided a complete taxonomy for this domain, other scholars have followed with their own popular interpretations. Again, these taxonomies are concerned with scales of achievement ranging from *imitation* to *naturalization* (Dave 1970), *perception* to *origination* (Simpson 1966), and *reflex* to *non-discursive* (Harrow 1972). From a design perspective, psychomotor skills can be considered to be the *hard-skills* or tools needed to design.

Psychomotor Domain: discipline-specific

One crucial skill of a Visual Designer is the physical ability to give form to a particular medium. Typographers often exhibit a mastery of drawing letterforms while contemporary visual designers have the ability to manipulate digital artifacts. From operating a letterpress machine to using

digital programs such as InDesign or Illustrator, the visual designer needs extensive training and practice to develop the necessary psychomotor skills to manipulate and operate the tools of their respective medium.

Psychomotor Domain: discipline-independent
As for the domain-independent abilities, visualizing, sketching, and diagramming are often considered to be fundamental. Visualizing takes place not only as a way to communicate complex information and ideas, but also as a sense-making activity. Sketching, in the traditional, sense works "both informally in the designer's skilled reading of drawings and imagining their implications, and more formally in measuring dimensions, calculating stresses, and so on" (Cross 2007, 34). Both visualizing and sketching allow the designer to "handle different levels of abstraction," "enable identification and recall of relevant knowledge," and "assist problem structuring through solution attempts" (Cross 2007, 57-58). Prototyping, in terms of construction or "form-giving"—regardless of medium—also affords the designer the same benefits of sketching and allows for rapid exploration of ideas and concepts. Visualizing, sketching, and prototyping are learned skills, and all are considered foundational skills to design regardless of discipline.

Furthermore, Design Research methods, under the philosophy of *human-centered-design*, can also be seen as tools that require psychomotor abilities. Hanington (2003) argues that the process to design in a human-centered fashion is inherently tied to the research of human needs and concerns . With this perspective, the capacity to use and apply human-centered research methods can be taken as an ability to use the tools of design. The categories of belief and adherence to design methods—as categorized by Hanington as *traditional*, *adaptive*, and *innovative*—is one way to understand disciplinary distinctions (2003).

Cognitive Domain

The cognitive domain formed the basis of Bloom's first study; however, recent developments distinguished between knowledge and cognitive processes (Anderson, Krathwohl and Bloom 2001). Factual Knowledge, or elemental knowledge, is comprised of the basic knowledge of terminology, details, and specifics. Conceptual Knowledge includes principles, models, and classifications that give shape and structure to the aforementioned Factual Knowledge. Procedural Knowledge describes the knowledge exercised in the doing of something; more specifically, Procedural Knowledge can include methods of inquiry and criteria for using skills or techniques. Finally, Metacognitive Knowledge—a new category not part of

the original taxonomy—consists of knowledge and awareness about one's own cognition, strategic knowledge, and contextual knowledge.

Factual Knowledge: discipline-specific
Factual Knowledge is the elemental pieces or "facts" taught in traditional design education. For the Visual Designer, Factual Knowledge consists of elements such as typeface identification, medium conventions, and historical references.

Factual Knowledge: discipline-independent
On the other hand, discipline-independent facts are inherently contradictory. All facts and elemental knowledge belong to a particular domain or discipline. In following this line of reasoning—especially when arguing for a transdisciplinary model of design—an integrative field of design does not and cannot create factual knowledge about a disciplinarily independent field.

Conceptual Knowledge: discipline-specific
Conceptual knowledge consists of the models and theories that pertain to specific fields. Visual designers are trained in concepts such as Color Theory, Semiotics, and Gestalt Theory that help shape factual knowledge. Other design disciplines may take on other conceptual knowledge that is often related to their respective medium of output. For example, Organizational design looks to strategy theories and business management practices while Service Design looks at marketing and economic theories.

Conceptual Knowledge: discipline-independent
Discipline-independent conceptual knowledge can be the explicit or declarative knowledge used to describe design. This is knowledge that is external to the act of designing; a designer, lacking in such discipline-independent conceptual knowledge, can quite possibly function extraordinarily well as a discipline specific designer. Historically, the progress made at establishing a discipline of design has focused on developing this conceptual knowledge of design. It is important to reiterate that declarative knowledge does not need to be empirical or positivist in nature; as exemplified by the early methods movement, the aims at creating conceptual knowledge of design based on the ideology of science has been widely rejected.

Nevertheless, the methods movement contributed greatly with theories and models to describe discipline-independent design. Knowledge from the "First-generation" methods aimed at describing the design process while "second-generation" methods aimed at describing the design situation (Bayazit 2004). Rittel's notion of "wicked-problems" is still one of the most

cited theories in describing the discipline of design. Similarly, Alexander's *Notes on the Synthesis of Form* and Simon's *The Science of the Artificial* are still considered to be essential contributions.

Fewer frameworks have been proposed in describing an integrative discipline of design. As noted in the review, Buchanan's repurposing of rhetoric as a foundation for design as an art of invention is an exception (2001). Recent revivals in systems theory and cybernetics have also contributed in providing a common language to describe design (Nelson and Stolterman 2003; Dubberly and Pangaro 2007).

Procedural Knowledge: discipline-specific

Procedural Knowledge takes into consideration the subject-specific skills, techniques, and methods exercised in the act of designing. Being less general than conceptual knowledge, designers often have a much more difficult time articulating the techniques and judgments that go into their designs. The choice of a typeface or color theme can be reinforced and influenced by conceptual and factual knowledge; however, such judgments for the Visual Designer are often tacit and are specific to a designer's experience and domain. Such tacit and unconscious knowledge commonly contribute to the understanding of design as a black box.

Procedural Knowledge: discipline-independent

However, a more pragmatic account has been understood about the procedural knowledge of design—moving away from both a romantic view of the "largely opaque... mystical" as well as the conservative view of the "rational... fully transparent" design process (Fallman 2003, 228). It is important to note here that all the knowledge aimed at understanding or describing the activity of design is itself conceptual knowledge. However, these concepts that articulate how designers think or behave differently helps clarify the notion of discipline-independent procedural knowledge. Articulating how designers design is certainly different from designing itself. Nonetheless, both Schon's Reflective Practitioner and Levi-Strauss' metaphor of "The Bricoleur" is a contribution that articulates the procedural knowledge exercised in the act of designing. Reflective Practice itself can be considered a behavior applicable to all disciplines include design.

The tacit and unconscious nature of procedural knowledge limits the understanding of how discipline-independent procedural knowledge develops; while common pedagogical thinking links the development of domain-specific procedural knowledge to development of discipline-independent abilities, this domain of design knowledge warrants more study.

Metacognitive Knowledge: discipline-specific

Finally, metacognitive knowledge makes up the last dimension category of the cognitive domain. This type of knowledge consists of the awareness of one's cognition, cognitive contexts, and general cognitive strategies. In other words, metacognitive knowledge involves knowing *how to think* and *when to think*. Similar to procedural knowledge, metacognitive knowledge is very much context specific. However, general strategies such as "trial-and-error"—while not always useful—extend to many different contexts. Awareness of one's cognition as well as understanding cognitive context is clearly discipline and individual-specific. On the other hand, as covered in the review on design cognition, general problem solving strategies such as *solution-finding* and *selective inattention* are exhibited in all aspects of design.

Metacognitive Knowledge: discipline-independent

Behavior of designers such as Lawson's study of design cognition—reasoning versus imagining—describes a metacognitive difference expressed by all designers (Lawson, Design Thinking). As mentioned earlier in the review, the designer's ability to "juggle" multiple perspectives is a fundamental problem-solving strategy that extends far beyond a specific field of design. Similarily, Schon's contribute of knowledge gained through a reflective conversation also applies; his concept of problem-framing, reframing, and frame-resolution are considered design truisms often explicitly embedded into the design process.

Affective Domain

Finally, the third domain of Bloom's Taxonomy is the Affective Domain. Simply put, the affective domain deals with the internalization of attitudes, values, and interests. While Krathwohl et al. (1964) offered different levels of achievement in this domain, this category is used here only as a means of discussing the importance of attitudes in design.

Affective Domain: discipline-specific

Professional organizations such as the American Institute of Graphic Arts (AIGA) or the Industrial Designers Society of America (IDSA) have long created professional codes of ethics that dealt "with issues of competence, integrity, and professionalism, emphasizing ethical standards in technical practice and education, in business matters, and in compliance with laws and regulatory codes associated with safety" (Buchanan 2005). While these professional and disciplinary organizations have their own specific values and attitudes—especially in terms of professional ethics—the attitude of design that sits across disciplinary boundaries is far more interesting.

Affective Domain: discipline-independent

The cross-disciplinary movements towards Human-Centered-Design and Participatory Design sprung from a strong adherence to a particular set of values and attitudes (Muller and Kuhn 1993). Even discussions on the importance of empathy with stakeholders and users often call into notions of values, attitudes and ethics; design is generally agreed to be a value-driven activity. Nelson and Stolterman argue that since all of design is "a matter of making good judgments," understanding one's "character" is all the more crucial (Nelson and Stolterman 2003, 290). This and much of the discourse around attitudes and ethics focus on the notion of design itself as part of the human condition. Moholy-Nagy, rather than perceiving design as a skill or discipline, understands design as an "attitude of resourcefulness and inventiveness which allows projects to be seen not in isolation but in relationship with the need of the individual and the community" (1947, 42). Nigel Cross (2007) identifies design as a *third culture of human knowledge* while Buchanan (1992a) links design directly with John Dewey's "internal operations" of men changing the environment to new ends. Buchanan further argues that when design is viewed in the larger context of human society, "the ethical problems of design are essentially the same as the ethical problems of citizenship and practical living in general" (2005, 507).

A designer's attitude from this perspective goes far beyond notions of design abilities. An emerging field of interest in the Philosophy of Design has emerged to consider such implications (Galle 2002). Design, as considered by the Philosophy of Design, is itself a human activity at the same levels of thinking and feeling. However, Per Galle does not discount the instrumental opportunities of the field and points the study of Philosophy of Design to help designers understand "what one is doing, rather than just understanding how to do" (Galle 2002, 217). Nevertheless, the affective domain remains a crucial and often unexplored domain of design abilities and development. Notions that design itself exists in the greater context of man, culture, and history only makes the need for clarification even greater.

CONCLUSION

The scholarly contributions of design have taken place in a relatively short timeframe, but as demonstrated through the paper, the understanding and knowledge of design is quite substantial. The literature review traced the development of the design disciplines towards a view of design separate from its arts and crafts tradition. Along the way, there has been extensive knowledge developed in establishing design as a separate epistemology that escapes the bounds and limitations of a technical rational tradition. Such progress has helped emerge the current state of discourse on models of design research and design knowledge creation.

The framework presented provides a way to understand design abilities and clarify the progress made in establishing design as a discipline-independent activity. Using Bloom's three domains of human development—psychomotor, cognitive, and affective—not only provide a clearer picture of what design abilities are, but also how design abilities can develop. From a pedagogical perspective, the popularity and stability of Bloom's Taxonomy leads credence to its usefulness in describing human development. Investigating the scales of achievement across the design abilities can offer insights on the development and learning of design abilities. The affective domain remains a ripe area for exploration. Even as a value-driven activity, how attitudes and values drive the development of Design knowledge and skills remain relatively unstudied.

Furthermore, investigating the relationship between the different domains can yield insights and a deeper understanding of design abilities. Take, for example, the topic of sketching; when considered as an interaction between the psychomotor domain and procedural knowledge under the cognitive domain, knowledge of sketching becomes a means of imagining and exploring concepts and ideas. In what Goldschmidt (1991) calls the "dialectics of sketching," multiple representations transform, articulate, and conflict the situation to bring clarity to the designer. This framework provides a language for future discussions on the distinctions, as well as the interactions, between the domains of design abilities.

Finally, the cognitive dimensions of factual knowledge, conceptual knowledge, procedural knowledge, and metacognitive knowledge help identify and classify the epistemological base for design. When looking

at new design fields of interest such a Service Design or Organizational Design, the framework also provides opportunities to understand what types of design abilities are *discipline-specific* or *discipline-independent*.

The beginning of this paper opposed the recent conversation on Design Thinking as relatively superficial and belying its complexity. However, the fact that such populist conversations exist has provided numerous opportunities for all disciplines of design. From designing services to strategy, never before have the audience be so willing to hear the voices and input of designers. But as design scholars and design practitioners step up to meet the challenges demanded by these new contexts for design, it is imperative that designers be cognizant of their abilities and knowledge. As the young field inevitably marches forward in establishing an "interdisciplinary discipline" (Cross 2007), Design will ultimately show itself to be a discipline without hierarchy, without boundaries, yet firmly rooted in its own claims of knowledge.

WORKS CITED

Alexander, C. (1964). Notes on the Synthesis of Form (6th Edition ed.). Cambridge: Harvard University Press.

Anderson, L. W., Krathwohl, D. R., & Bloom, B. S. (2001). A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives. New York: Longman.

Archer, B. (1981). A View of the Nature of Design Research. In R. Jacques, & J. A. Powell (Ed.), Proceedings from the 1980 Design Research Society Conference. Guildford: Westbury House.

Bayazit, N. (2004). Investigating Design: A Review of Forty Years of Design Research. Design Issues , 20 (1), 16-29.

Blevis, E., & Stolterman, E. (2009, September). Transcending Disciplinary Boundaries in Interaction Design. interactions , pp. 48-51.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). The Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain. New York: Longman.

Boland, R. J., & Collopy, F. (2004). Managing as Designing. Stanford, CA: Stanford University Press.

Brown, T. (2008, June). Design Thinking. Harvard Business Review , 84-92.

Buchanan, R. (1992a, January). Design and Technology in the Second Copernican Revolution. International Journal of Design Sciences and Technology .

Buchanan, R. (2001). Design and the New Rhetoric: Productive Arts in the Philosophy of Culture . Philosophy and Rhetoric , 34 (3), 183-206.

Buchanan, R. (2005). Design Ethics. In C. Mitcham, Encyclopedia of Science, Technology, and Ethics (pp. 504-509). Gale Cengage.

Buchanan, R. (2001). Design Research and the New Learning. Design Issues , 17 (4), 3-23.

Buchanan, R. (1992b). Wicked Problems in Design Thinking. Design Issues , 5-21.

Cross, N. (2007). Designerly Ways of Knowing. London: Springer.

Cross, N. (1984). Developments in Design Methodology. New York: Wiley.

Dave, R. (1970). Psychomotor Levels. In R. Armstrong, Developing and writing educational objectives (pp. 33-34). Tucson: Educational Innovators Press.

Dubberly, H., & Pangaro, P. (2007). Cybernetics and Service-Craft: Language for Behavior-Focused Design. Kybernetes .

Dunne, D., & Martin, R. L. (2006). Design Thinking and How It Will Change Management Education: An Interview and

Discussion. Academy of Management Learning and Education , 5 (4), 512-523.

Fallman, D. (2003). Design-Oriented Human-Computer Interaction. Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 225-232). New York: ACM.

Fallman, D. (2008). The Interaction Design Research Triangle of Design Practice, Design Studies, and Design Exploration. Design Issues , 24 (3), 4-18.

Galle, P. (2002). Philosophy of design: an editorial introduction. Design Studies , 23 (3), 211-218.

Goldschmidt, G. (1997). Capturing indeterminism: representation in the design problem space. Design Studies , 18 (4), 441-456.

Goldschmidt, G. (1991). The dialectics of sketching. Creativity Research Journal , 4 (2), 123-143.

Hall, S. (2007). This means this, this means that: a user's guide to semiotics. London: Laurence King.

Hanington, B. (2003). Methods in the Making. Design Issues , 19 (4).

Harrison, S., Sengers, P., & Tatar, D. (2006). The three paradigms of HCI. Alt. chi. Proceedings of CHI '07. New York: ACM.

Harrow, A. J. (1972). A taxonomy of the psychomotor domain: A guide for developing behavioral objectives. New York: David McKay.

Hillier, B., Musgrove, J., & O'Sullivan, P. (1984). Knowledge and Design. In D. i. Methodology, Cross, Nigel (pp. 245–264). New York: Wiley.

Kotler, P., & Rather, A. G. (1984). Design: a powerful but neglected strategic tool. Journal of Business Strategy , 5 (2), 16-21.

Krathwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). Taxonomy of educational objectives: Handbook II: Affective domain. New York: David McKay Co.

Krippendorff, K. (2006). The semantic turn: a new foundation for design. New York: CRC Press.

Lang, J. (1987). Creating Architectural Theory: The Role of the Behavioral Sciences in Environmental Design . New York: Van Nostrand Reinhold Co.

Lawson, B. (1979). Cognitive Strategies in Architectural Design. Ergonomics , 22 (1), 59-68.

Lawson, B. (2006). How designers think: the design process demystified (4th Edition ed.). Oxford: Elsevier.

Louridas, P. (1999). Design as bricolage: anthropology meets design thinking. Design Studies , 20 (6), 517-535.

Martin, R. L. (2009). Opposable Mind: Winning Through Integrative Thinking. Boston: Harvard Business Press.

Moholy-Nagy, L. (1947). Vision in Motion. Chicago: Paul Theobald & Company.

Muller, M. J., & Kuhn, S. (1993). Participatory design. Communications of the ACM , 36 (6), 24-28.

Nelson, H. G., & Stolterman, E. (2003). The Design Way: intentional change in an unpredictable world. Englewood Cliffs: Educational Technology Publications.

Rittel, H., & Webber, M. (1973). Dilemmas in a General Theory of Planning. Policy Sciences , 4.

Rowe, P. G. (1987). Design Thinking. Cambridge, MA: The MIT Press.

Schön, D. A. (1983). The reflective practitioner: how professionals think in action. New York: Basic Books.

Simon, H. A. (1969). The Sciences of the Artificial (1st Edition ed.).

Cambridge: MIT Press.

Simon, H. A. (1973). The structure of Ill-structured problems. Artificial Intelligence , 4 (3-4), 181-201.

Simpson, E. J. (1966). The Classification of Educational Objectives, Psychomotor Domain. University of Illinois, Urbana.

Steup, M. (2005, December 12). Epistemology. (E. N. Zalta, Ed.) Retrieved January 1, 2010 from Stanford Encyclopedia of Philosophy: http://plato.stanford.edu/entries/epistemology/

Wikipedia contributors. (n.d.). Epistemology. Retrieved January 1, 2010 from Wikipedia, The Free Encyclopedia: http://en.wikipedia.org/wiki/Epistemology

Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research Through Design as a Method for Interaction Design Research in HCI. Proceedings of the SIGCHI conference on Human factors in computing systems (pp. 493-502). New York: ACM.