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Four Criteria for Design Theories

Abstract The goal of this paper is to demonstrate that the adoption of the four criteria we outline will strengthen future design theories and encourage existing design theories to expand or reconfigure in useful directions. We propose four criteria for design theory creation and evaluation. These are (1) the theory should have substantial design applications, and be applicable to any topic; (2) the theory should use propositions – if-then language – as a way of describing, explaining, and predicting actual and existing aspects of designing; (3) where appropriate, a new theory should accept and adopt propositions and language contained in other design theories; and (4) the theory should accommodate, or at least acknowledge, generative activity. We are not proposing a new general design theory – this paper outlines a strong approach to studying and building theory. Please also note that this essay does not pretend to exhaust a topic that has been discussed for at least the last 50 years.

1 Herbert A. Simon, *The Sciences of the Artificial*, 3rd ed. (Cambridge, MA: MIT Press, 1969).

2 Nigel Cross, "Design Research: A Disciplined Conversation," *Design Issues* 15, no. 2 (1999): 5–10; Nigel Cross, *Designerly Ways of Knowing* (London: Springer, 2006).

3 For example, see Klaus Krippendorff, *The Semantic Turn: A New Foundation for Design* (Boca Raton: CRC Press Taylor & Francis Group, 2006); Terence Love, "A Unified Basis for Design Research and Theory," in *International Design Congress-IASDR 2005: New Design Paradigms* (Douliou, Taiwan: International Association of Societies of Design Research, 2005); Wolfgang Jonas, "Design Research and Its Meaning to the Methodological Development of the Discipline," in *Design Research Now*, ed. Ralf Michel (Basel: Birkhäuser, 2007), 187–206; Sandeep Purao et al., "The Sciences of Design: Observations on an Emerging Field" (working paper 09-056, Harvard Business School, Cambridge, 2008), accessed March 8, 2017, http://www.hbs.edu/faculty/Publication%20Files/09-056.pdf; Frances Joseph, "Mnemotechne of Design—Ontology and Design Research Theories" (PhD dissertation, Auckland University of Technology, 2010), http://aut.researchgateway.ac.nz/handle/10292/1205.

4 Julie Rivkin and Michael Ryan, *Literary Theory: An Anthology*, 2nd ed. (Malden: Blackwell Publishing, 2004).

5 For example, see Cross, "Design Research" and *Designerly Ways*; William Gaver, "What Should We Expect from Research Through Design?," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ed. Joseph A. Konstan, Ed Chi, and Kristina Höök (New York: ACM, 2012): 937–46; Lassi A. Liikkanen, *Design Cognition for Conceptual Design* (Helsinki: Aalto University, 2010), accessed March 18, 2017, https://aaltodoc.aalto.fi/bitstream/handle/123456789/4745/isbn9789526030258.pdf?sequence=1&isAllowed=y.

6 Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4, no. 2 (1973): 155–69.

Introduction

The motivation for this work began with the concept of the science of design,[1] which studies design phenomena, whether process or artifact. At the same time, as pointed out for example by Cross,[2] framing the science of design using theories drawn from either the traditional sciences or the humanities is problematic. Design research academics have long struggled with different — sometimes contradictory — definitions and interpretations of key terms, including *theory*, *research*, *design practice*, and others.[3]

The word theory, for example, has been employed in at least two ways:
- to connote a general, systematic understanding of phenomena that lends itself to hypotheses that are testable through repeatable observations (typically used in science); and
- as a useful lens with which to produce an interpretation of an object under study (typically used in the humanities).

We understand the definition of theory in the sciences as a subset of the larger definition of theory in the humanities, since it has more specific criteria to meet. The scientific lens is only one such perspective — there are many. A quick review of the table of contents of Rivkin and Ryan's *Literary Theory: An Anthology*[4] provides a list of more than a dozen such perspectives. Yet neither the scientific nor the humanities approach is entirely satisfactory for design, which must accommodate generativity as a central concern.[5] As a result of these reflections, we propose that a theory in design should address the criteria presented in this article.

Method

We developed the following criteria through extended discussion and debate among a group of 6 researchers (the authors) representing different design research areas across four American countries — Brazil, Canada, Colombia, and the USA. The researchers are linked to design research and also have training and experience in the humanities, engineering, architecture, and computer science. The way we have complied this essay is not entirely structured. Taking our cues from key references in the design literature, each meeting either led to the next step or changed our trajectory. Sometimes we authors sought to build a consensus; at other times, divergence remained. Hence, the process was characteristic of that found when addressing ill-structured problems.[6]

During 12 meetings, each 3 hours long, we worked through existing proposals for criteria that should be met by a theory of design,[7] producing a master list of roughly 50 factors that could, ideally, be addressed by a theory, and finally consolidating those factors into the criteria that we propose in this paper. We are conscious, however, that this discussion does not pretend to exhaust the topic, which has been debated for at least the last 50 years.[8]

Design Practice

One of the most fundamental definitions given to the words *design practice* is from Herbert Simon, who states, "Everyone designs who devises courses of action aimed at changing existing situations into preferred ones."[9] This simple definition carries several implications.

Firstly, Simon's definition associates the design process with the kind of thinking that leads to the *construction* of possible future worlds. Often, the act of designing implies working with incertitude, taking risks, and building several possible paths in a non-linear way. In this sense, design practice is essentially a

generative activity. However, designers do more than construct or generate material objects, systems, experiences, and so on. Through complex, systematic practices, designing also adjusts, improves, and invents/discovers/constructs new understandings, which in turn contribute to the generation of some useful new artifact.[10] Krippendorff says that the practice of design passes through five stages – moving from the formulation of useful and functional products to the construction of discourses. Discourses are seen as the tension between continuity and conservatism with a desire for change. To Krippendorff "the semantic turn is a seed for design to redesign itself by means of its own discourse."[11] In other words, the final stage of design is the production of some kind of new knowledge – typically within a specific context – that answers questions like what are the conditions for a memorable experience? or what meanings are associated with this new artifact?

Simon's initial reflections about the role of knowledge in design points to another important notion – design practice is a *learning* activity that is at once *exploratory*, *evolutionary*, and *constructive*. Beyond the learning that goes into creating a new artifact, it is even possible to consider the practice of design as a special method for *knowledge construction*.[12] During the design process, explicit knowledge is generated and becomes tangible for every actor involved. People are changed by it. Such new knowledge also produces new meanings and helps to establish new or previously unarticulated connections, associations, and concepts.

A third implication of Simon's definition is that design, more often than not, deals with complexity. As Morin defines it, complexity always involves uncertainty:

> "Complexity includes not only amounts of units and interactions that challenge our calculation possibilities: it also comprises uncertainties, indeterminations, and random phenomena. Complexity, in a certain sense, is *always related to uncertainty*."[13]

Design activity is itself complex.[14] Designing moves through stages where construction is fully controlled, partly controlled, and totally indeterminate,[15] again pointing to design's exploratory nature. Designers search for the novel by conducting research of diverse natures – sometimes designers follow a systematic and structured logic to generate knowledge that will be useful to the project, while other moments in the process are more intuitive and less controlled so that unexpected elements appear.[16] Research strategies typically used by practicing designers might have their origins in science or social science. For example, designers commonly conduct surveys and employ ethnographic-inspired research, and the results are often subjected to statistical data analyses. However, it is more difficult to associate the activity of design with a scientific task of a scholarly nature. In science, one searches for general principles that can explain phenomena, typically by using either inductive or deductive logic. A design project, on the other hand, can be contextually specific or situational,[17] and standards of validity can be quite fluid, depending on the requirements of the case. Often the design team itself evaluates the validity of both the data collection and analysis – sometimes in consultation with the client.

The scholarly community is commonly seen as the arbiter of knowledge validation in science – even if this knowledge should not necessarily be considered true or false, but rather based on a stronger or a weaker case. Design, on the other hand, tends to proceed using abductive reasoning. In *An Anthology of Theories and Models of Design*, Toshiharu Taura proposes three types of inferences for what he defines as the pre-design stage:

> "Deduction that means to infer (deduce) an individual instance from a general principle or law (deterministic); induction that means to generalize (induce) a set of instances or observations (semi-nondeterministic); and abduction

7 Examples included Amaresh Chakrabarti and Lucienne T.M. Blessing, eds., *An Anthology of Theories and Models of Design: Philosophy, Approaches and Empirical Explorations* (London: Springer, 2014); and Shirley Gregor and David Jones, "The Anatomy of a Design Theory," *Journal of the Association for Information Systems* 8, no. 5 (2007): 313–35.

8 For example, see Cross, "Design Research"; Ken Friedman, "Theory Construction in Design Research: Criteria: Approaches, and Methods," *Design Studies* 24, no. 6 (2003): 507–22; and Nigan Bayazit, "Investigating Design: A Review of Forty Years of Design Research," *Design Issues* 20, no. 1 (2004): 16–29.

9 Simon, *Sciences of the Artificial*, 111.

10 *Artifact*, in this sense, could mean *product*, *system*, *service*, *environment*, or even *experience*. The word *useful* could also be perceived in a wider sense not exclusively related to technical or material functions.

11 Krippendorff, *The Semantic Turn*, 12.

12 Armand Hatchuel, Pascal Le Masson, and Benoît Weil, "From R&D to RID: Design Strategies and the Management of Innovation Fields," in *Proceedings of the EIASM 8th International Product Development Management Conference*, ed. O.A.M and H. Boer (Brussels: EIASM, 2001): 415–30.

13 Edgar Morin, *Introduction à la Pensée Complexe* (Paris: Seuil, 2005), 48.

14 For example, see Dan Braha and Oded Maimon, "The Measurement of a Design Structural and Functional Complexity," *IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans* 28, no. 4 (1998): 527–35; and Waguih ElMaraghy, "Complexity in Engineering Designs and Manufacturing," *CIRP Annals: Manufacturing Technology* 61, no. 29 (2012): 793–814.

15 Kees Dorst, "The Problem of Design Problems," in *Proceedings of the 6th Design Thinking Research Symposium: Expertise in Design*, ed. Nigel Cross and Ernest Edmonds (Sydney:

University of Technology Sydney, 2003): 135–47.

16 Donald A. Schön, *The Reflective Practitioner: How Professionals Think in Action* (New York: Basic Books, 1983).

17 Jesper Simonsen et al., eds., *Situated Design Methods* (Cambridge, MA: MIT Press, 2014).

18 Toshiharu Taura, "Motive of Design: Roles of Pre- and Post-design in Highly Advanced Products," in Amaresh Chakrabarti and Lucienne T.M. Blessing, eds., *An Anthology of Theories and Models of Design: Philosophy, Approaches and Empirical Explorations* (London: Springer, 2014), 85.

19 For example, see Prasad Boradkar, "Design as Problem Solving," in *The Oxford Handbook of Interdisciplinarity*, ed. Robert Frodeman, Julie Thompson-Klein, and Carl Micham (Oxford: Oxford University Press, 2010): 273–87.

20 Some would argue that the term *discovery* is more appropriate than *invention* where knowledge is concerned. However, in design practice, the meaning of discovery is associated with the heuristic nature of the process, where the aim is to achieve something without knowing how to achieve it, or where to look.

21 Christopher Frayling, "Research in Art and Design," *Royal College of Art Research Papers* 1, no. 1 (1993): 1–5.

22 Simonsen et al., *Situated Design Practices.*

23 For example, see John S. Gero and Udo Kannengiesser, "The Situated Function – Behaviour – Structure Framework," in *Artificial Intelligence in Design'02*, ed. John S. Gero (Dordrecht: Kluwer Academic Publishers, 2002), 89–104.

24 Rittel and Webber, "Dilemmas," 155–69.

that means to create a possible hypothesis that explains a set of observations (non-deterministic)."[18]

Thus, if design is not science, the question remains — when is it possible to call design research a scholarly pursuit? We now address this question.

Design Research and Scholarly Activity

The term *research* is another poorly-defined key concept in design — and one broadly used by design academics in at least two distinct ways (see Figure 1).

Firstly, the word research denotes the search for information during the design process. Research data is gathered primarily to support the creation of a satisfactory outcome — for example a thing — for a specific project.[19]

Secondly, the term research indicates the pursuit of new knowledge using design phenomena as the object of investigation. This kind of search could be categorized as either *scientific research* or *scholarly research*. Scientific research is subject to relatively strict standards of validity — effects of causes are often not proven directly, but are instead given a likelihood of having not occurred randomly. Scholarly testing and research, on the other hand, includes (but is not limited to) this approach. Instead, it often seeks to understand greater human, interpersonal, and cultural phenomena that may include design. Scholarly research is also subject to relatively strict standards of validity, but not in the same sense as scientific testing. In either case, the scope or ultimate purpose of the activity might be relatively constrained — an *adjustment* to existing things or existing reusable knowledge, for example — or relatively dramatic — like the *invention* of new artifacts, or new knowledge.[20] As Figure 1 shows, both design practice and design research lead to the creation of artifacts. However, while this result is the goal of design practice, in design research artifacts are created as part of the pursuit for new knowledge.

In his 1993 work about research in the arts, media, and design,[21] Christopher Frayling discusses the influence of *learning by doing* in design. He proposes three different approaches to learning — research about design, research for design, and research through design. The research portion of design practice could be categorized as *research for design*, meaning that the knowledge it collects and synthesizes contributes to the wider design process. Frayling's ideas have evolved, and have been interpreted by many scholars. Some researchers thus emphasize the role of practice and the results implicit in the artifact, while others declare the importance of making a contribution to the field through scholarly publication of the knowledge and reflections that emerged during the design process. This knowledge is subject to close scrutiny and quite stringent standards of validation, since the intention is to apply it to other situations.

Because design practice is situational,[22] some scholarly design researchers have incorporated situatedness into their models.[23] Whether design as a scholarly research activity is less situational is debatable. On the one hand, reusable knowledge is not necessarily situated in the same way as project knowledge. On the other hand, if the topic of scholarly study is the development of plans to change the existing into the preferred, design theory seemingly must have a situational character as well.

The term *situational* refers to the context of a specific design problem and, by extension, to the context of the actors involved in solving it. Many of today's design problems are ill-structured,[24] because they arise in complex socio-technical networks and systems. Understanding that character also informs the design process and the lived experience of the actors involved in the process.

Although a specific design is rarely meant to be reproduced in other situations,
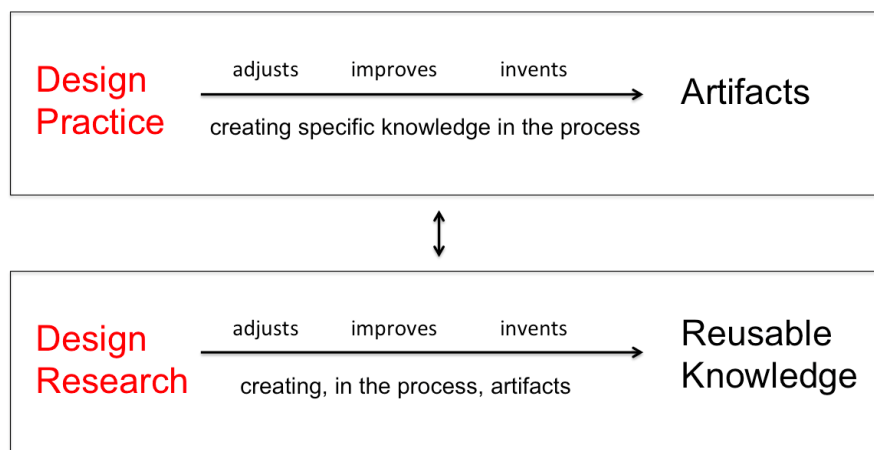
if one considers design practice as a permanent learning process, then *design experience* could be applicable to future situations. The goal of scholarly design research is to make knowledge available on a broader scale. It does this by attempting to investigate design phenomena, trying to identify patterns,[25] constructing theories, developing methods, or even in some cases creating new technologies. One could categorize this activity as *scholarly design research*. The strategies employed are usually different from research for design. Scholarly design research should work with the same level of rigor used in traditional sciences or humanities. Nigel Cross has tried to resolve these difficulties by separating design research into two separate concepts – design science and design discipline. Referring to Grant, he proposes, "design as an activity may be the subject of scientific investigation."[26] Reflecting upon the notion of design science, Cross proposes the idea that the study of design:

> "includes the study of how designers work and think, the establishment of appropriate structures for the design process, the development and application of new design methods, techniques and procedures, and reflection on the nature and extent of design knowledge and its application to design problems."[27]

The proximity of design practice to scholarly design research, shown in Figure 1, demonstrates the close relationship between the two. Frequently, scholarly design researchers will promote, participate in, or simply observe a specific design practice, trying to produce knowledge that can be applied to other, similar situations. Usually, this kind of research is categorized as Research Through Design.[28] On the other hand, a scholarly design researcher might develop not just reusable knowledge, but also new artifacts produced during research activity.

Arriving at a Notion of Theory

Several issues arose repeatedly during the discussions we co-authors held, which served to guide our discussions, and eventually shape the arguments we set forth in this paper. These issues were: (1) the relationship between design as practice and design as scholarly investigation; (2) the position of design research relative to other research fields; (3) what a theory has to attempt to be considered a theory; and (4) trends in scholarly design research and design practice.

The first issue addresses the difficulty of separating design practice from design research, as discussed above. Figure 1 indicates that design research is often intrinsically linked to practice, and the double-sided arrow in Figure 1 indicates that design practice and design research have the potential to inform one another at any point. A theory usually has practice as its object of observation, or alternatively, it influences the practice with its propositions.

25 For example, see Christopher Alexander, Sara Ishikawa, and Murray Silverstein, *A Pattern Language: Towns, Buildings, Construction* (New York: Oxford University Press, 1977).

26 Donald P. Grant, "Design Methodology and Design Methods," *Design Methods and Theories* 13, no. 1 (1979), quoted in Nigel Cross, "Designerly Ways of Knowing: Design Discipline versus Design Science," *Design Issues* 17, no. 3 (2001): 53.

27 Nigel Cross ed., *Developments in Design Methodology* (Chichester, NY: John Wiley and Sons, 1984), 53.

28 Frayling, "Research in Art and Design," 1–5.

Figure 2 Three different models of how design research may be related to the disciplines of science and the humanities.
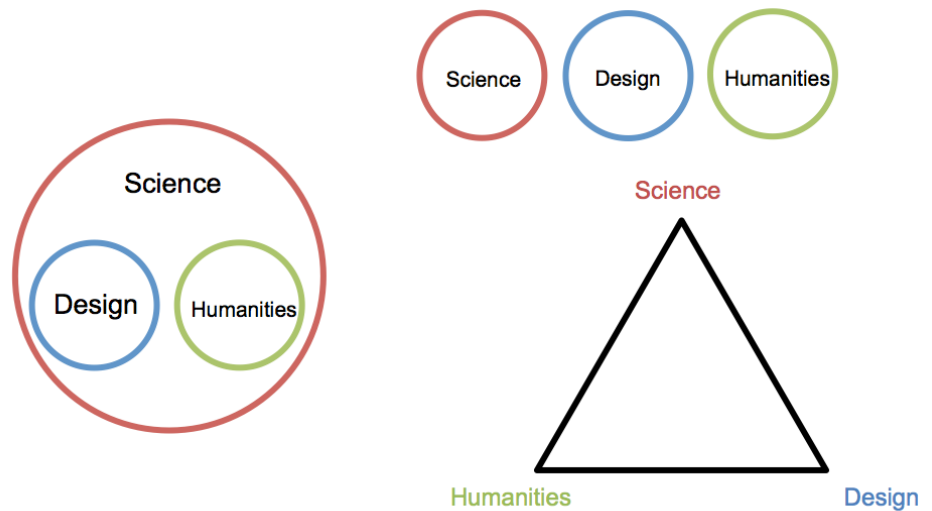
29 Simon, *Sciences of the Artificial*.

30 Victor Margolin, *Design Discourse: History Theory Criticism* (Chicago: University of Chicago Press, 1989), 7.

31 Cross, *Designerly Ways*, 2–9.

32 Wayne C. Booth, Gregory G. Colomb, and Joseph M. Williams, *The Craft of Research* (Chicago: University of Chicago Press, 1995).

33 Lisa M. Given, ed., *The Sage Encyclopedia of Qualitative Research Methods* (Los Angeles: Sage, 2008), s.v. "theory," 876.

The second issue considers where design research is positioned in relation to other research areas, and to what extent design research is a specific field of investigation. Some authors propose that design research is a component of a larger, more general group called science, as originally advocated by Simon.[29] Often social science is included under this umbrella. Margolin[30] says that "we cannot conceive of any theory of design that is independent of a theory of society." Other authors associate design with scholarly research in the humanities, where the goal is not to prove a case but instead to multiply valid interpretations. An alternative notion (Figure 2) considers design research to be a unique and specific form of investigation related to, yet separate from, the sciences and the humanities.[31]

The triangle at the bottom of Figure 2 is a depiction of the character we believe a design theory should have. Both in science and in the humanities, theories must leave room for and be able to dialogue with other valid theories. A theory should always seek a more abstract and wider understanding of the phenomenon under study, since that is what differentiates theory from practice. This greater understanding of a particular object of study is what allows a theory to be broadly applicable in other, similar situations. A theory must always create space for new observations, which may even put the theory itself into question. Drawing on Booth et al.,[32] we believe that a theory should have three key qualities:

- it should be *contestable* — the theory should suggest a way of seeing things that has not already been well established;
- it should be *defensible* — it should be possible to produce reasonable (to the mind of an expert) evidence to validate it; and
- it should be *substantive* — the theory should have enough significance to merit its exploration and validation.

According to *The Sage Encyclopedia of Qualitative Research Methods*, a theory is:
"normally used to denote a model or set of concepts and propositions that pertains to some actual phenomena; a theory can provide understanding of these phenomena or form the basis for action with respect to them."[33]

From our perspective, a theory is a model of current understanding with the potential to inform future understanding.

Our fourth theme concerned trends in both scholarly design research and design practice. A design theory must be able to apply to the evolution of design. Conversely, new design practices can lead to new theories of design.

Terms that Shape Theories

Finally, during our discussions, we addressed some key design vocabulary – words and phrases – that will be of interest to scholarly design researchers. We propose here approximately 50 characteristic factors (Figure 3) of design. This was an exploratory exercise in granularity – undoubtedly there are many other possible topics to investigate, dissect, and include. However traditional or incomplete this list may be, it shows that even the most basic concepts we use in design can clearly be associated with other research domains like art or technology, or with more compositional, aesthetic design practices. The list also demonstrates that interdisciplinary research interests such as cognition, perception, sociability, and user experience, as well as the influence of human factors, economic factors, and other disciplines, are often part of design.

Abstraction	Falsifiability	Refutability
Artifact	Function	Representation
Arts	Games	(draw, prototype, model)
Behavior	Generation	Rhetoric
Cognition	Goal/intention/objective	Satisficing
Communication	Ideals/ideology	Semiotics
Composition	Innovation (novelty)	Situation/context/environment
Constraints	Inputs/(requirements)	Sociability
Creativity	Interaction	Structure/form
Culture	Iteration	Style/aesthetic
Design methods/planning	Knowledge	Technology
Designer	Meaning	Theory accommodation
Economic factors	Other disciplines	Uncertainty
Education	Perception	User
Emotion	Problem solving	User experience
Evaluation	Process	Validity
Expressiveness of designer	Reasoning	
(opinion, belief, preference)	Reflection/reflexivity	

Figure 3   Factors associated with a theory of design.

If we accept the notion that a design theory must be attentive to the processes involved in design practice, we see the importance of the terms *methods* and *problem-solving* – two topics widely studied by the scholarly design community since the 1960s. The use of a domain language – *drawings*, *mockups*, *prototypes* – reminds us that often design theories will reflect on the *representation* of something that does not yet exist. How can we represent the future? One must create something that gestures in the direction of a possible future, and in that creation, a step is taken into a future that contains this new gesture. Thus, *creativity*, *imagination*, *cognition*, *reasoning* and *communication* are themes related by process to the concepts of *representation* and *generativity*.

Though not new, some more recent themes are *experience*, *interaction*, *emotion*, *co-design* and *participatory* design. Again, the inter- and trans-disciplinary characteristic of design demands a conversation between diverse knowledge areas. Moreover, one way to characterize design is to say that it is the process of creating mediating artifacts.[34] Another recurring theme in the discussions was design as *rhetoric* or as *discourse*,[35] which often led to another issue, the *political* aspects of design.[36] Going further, design should not be restricted in its attention to objects, communications, services, or experiences, but should continue its expansion into *strategies* and *policies*. Strategies and policies maintain a fairly close relationship to *ideals*, *ideology*, and even *ethics*. Batya Friedman and her colleagues'[37] recent work in value-based design suggests that design theory similarly maintains an ontologically close

34 Young Ae Hahn, "Semiotic Constituents and Abstractness of Mediating Artifacts in Design Research" (PhD dissertation, The Institute of Design, Illinois Institute of Technology, 2009), ProQuest (AAT 3370897).

35 For example, see Margolin, *Design Discourse*; and Richard Buchanan, "Design and the New Rhetoric: Productive Arts in the Philosophy of Culture," *Philosophy and Rhetoric* 34, no. 3 (2001): 183–206.

36 For example, see Langdon Winner, "Do Artifacts Have Politics?," in *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago: University of Chicago Press, 1986), 19–39.

37 Batya Friedman, Peter H. Kahn Jr., and Alan Borning, "Value Sensitive Design and Information Systems," in *Early*

Engagement and New Technologies: Opening up the Laboratory, ed. Neelke Doorn, Daan Schuurbiers, Ibo van de Poel, and Michael E. Gorman (Rotterdam: Springer Netherlands, 2013), 55–95.

38 For example, see Armand Hatchuel and Benoit Weil, "A New Approach of Innovative Design: An Introduction to C-K Theory," in *DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design, Stockholm*, ed. A. Folkeson, K. Gralen, M. Norell, and U. Sellgren (Bristol: The Design Society, 2003), 109–125; Dorst, "The Problem of Design Problems," 135–47.

39 See Tetsuo Tomiyama, "Design Theory and Methodology for Engineering Design Practices," in *Design Integrations: Research and Collaboration*, ed. Sharon Poggenpohl and Keiichi Sato (Chicago: Intellect, The University of Chicago Press, 2009), 49–66.

relationship with areas such as philosophy, sociology, and economics. Designers often argue that they are poorly understood by organizations and their role is not seen as relevant.

The word *culture* is perhaps a little lost in the list, which belies its importance. Culture can be interpreted in several ways, but here we associate it with the *artificial*, or design as something that is made (by people) that changes the natural world to achieve certain outcomes. In some cases, these outcomes are related to specific goals, which in turn could associate them with decision-making processes—another concept that causes difficulty. We know that the problem-space co-evolves with the solving-space.[38] How can we make responsible decisions about something that has not yet been built? It is not just a process of analysis-synthesis because the generative character of a design constantly reshapes goals to be achieved during the process of creating the new. In addition, the extensive, pervasive, and dynamic nature of knowledge creation, and the interconnectedness of networked systems, means we are continuously creating social and technological experiments in complexity with no way to predict the many consequences. This state of affairs indicates progress in design theory is even more urgent.

The aspects in Figure 3 were extensively discussed and debated, grouped and regrouped, and sorted and associated. Our conversation eventually led to the formulation of a set of four criteria that a theory of design should try to meet. The criteria are not entirely distinct—some are implied by others or inherent in others, but we felt it would be useful to explicitly unpack their possibilities using the logic by which we understood them.

Summary of Four Criteria for Design Theories

1. The theory should have a broad scope for design application, but should be able to deal with any topic.

The theory might attach to an entire process or to part of the process, but it is important that a design theory deal with design, in the same way that a theory in physics deals with physical phenomena or theory in medicine refers to health. To put it another way, the proper subject of a design theory is design. If the subject were to be something else, like design outcomes, then there is no need for a special category of theories—those arising in other, non-generative disciplines will suffice. Some may object that all design theories are connected to design practice, but we felt this criterion should be included because theories exist that were not intended to do this. A classic example is the original formulation of *General Design Theory*[39] where the designer is considered as having perfect knowledge in order to map 1:1—rather than a 1:many—from goals to features. The same is true in other fields, where underlying predictive models are not necessarily predicting something that is intended for practical use. An example is the model of Hilbert space in mathematics.

Design practice is also a complex subject area—it has many aspects that are amenable to theorizing. A theory of design may be interested in how design decisions between various stakeholders are taken. Who are these actors, and how do they behave? What form(s) of reasoning do they apply? If the goal is to modify an existing situation into a desired one, how is the design problem produced? If we assume that design activity generates possible futures or artifacts that do not yet exist, then representation theories become appropriate. How do designers communicate their ideas? Conversation theories are also an important part of design research. If design activity is situational, understanding the context becomes essential. Generating and building operational models is also directly linked to design. What kinds of models do designers use, and how can they be structured?

In addition, as design naturally works with and in other fields, part of a theory's application to design practice may include trans/inter/multi-disciplinarity.

2. The theory should use **propositions** *– if-then language – as a way of describing, explaining and predicting actual and existing aspects of designing and design success; however this is defined.* [40]

A theory that presents itself using the language of propositional logic is going to be easier to understand and relate to other theories than one that does not use propositions. By propositions, we mean statements that can be validated through arguments that combine evidence and reasoning. Propositions can describe, explain, and predict – using all three types will contribute to their overall effectiveness as tools to strengthen the validity of a theory.

By its nature, a proposition is open to discussion, experimentation, observation, and interpretation. It is in this way distinguished from an axiom, imperative, or even a description.

We suggest that a theory's formulation should contain some indication of what criteria might be used to distinguish among design solutions in a terrain that involves success and failure. Such criteria would also serve to help establish the natural application area of the theory. For instance, many design theories that take a more technical approach do not explicitly deal with human satisfaction as an evaluation criterion. It would, therefore, be inappropriate to expect these kinds of theories to align well with situations where human satisfaction is a primary factor – unless they have been augmented with additional attention to human behavior and social constructs.

3. Where appropriate, the new theory should accept propositions and language contained in other design theories.

In some disciplines, it is normal for one theory to compete with another since each theory suggests a way of understanding phenomena that may exclude other ways of understanding them. For instance, the earth either revolves around the sun or else the sun revolves around the earth. One theory precludes the other, and once one is established, there are a variety of implications that arise, both for having accepted it and also for having rejected others.

However, in other disciplines, particularly in the humanities and social sciences, it is possible for theories to co-exist, since the point is not to establish a single truth, but instead to produce multiple valid ways of understanding that can be applied to various objects of study. Arguably, this approach should also apply to design theories, since design is a phenomenon that is socially constructed. This multiplicity of understanding is characteristic of design, where the standard approach is not to suggest that there is one ideal design and the designer's job is to find it. Instead, the designer typically recognizes that there is a wide range of possible ways to move from the current situation to a set of possible preferred situations. Designers and clients then choose among the preferred situations, depending on a variety of factors and the relative weight and impact of those factors.

Similarly, design theories that privilege one set of factors do not necessarily negate or replace design theories that privilege another set of factors. A design theory that models the factors that go into the design of a new piece of technical equipment, for example, does not necessarily need to accommodate the people who will be using the equipment. However, a design theory that models the political understanding surrounding that piece of equipment will need to include human, social, and cultural elements. The two theories are for different purposes, although they share the piece of equipment as an object of study.

In addition to the paradigm of acknowledging and accepting the co-existence

41 This review included those summarized in Chakrabarti and Blessing's *An Anthology of Theories and Models of Design.*

of multiple theories, this criterion also proposes re-using language from previous work. Two reasons exist to preserve language where possible. Firstly, it is just good manners. Secondly, a discipline can easily get bogged down in a proliferation of terms that relate to the same ideas, or conversely a paucity of terms that results in the same one being used differently by each scholar. In our review of existing design theories,[41] we found that this practice has not been widely observed.

4. The theory should accommodate – or at least acknowledge – generative activity.

Although analysis is important in disciplines such as computer science, engineering, and math, if we view these as scholarly fields where the primary purpose is to analyze and invent, then they share this generative characteristic with design. A design theory that does not acknowledge the generative nature of design might be a good theory, but it is going to be missing an important aspect of the object of study. Examples of the kinds of theories that might not meet this criterion are those that deal with the role of artifacts in society, which are more appropriately theories from anthropology, sociology, psychology, or science and technology studies (STS).

However, at this point, it is not necessary to spell out, except as examples, the kinds of generative processes that might be relevant. Some possible examples are the cognitive processes of creativity – like expansion, combination, analogy, intuition, synthesis, and the logic of abduction.

Conclusions

This paper is the result of an extended discussion among scholarly design researchers who also have experience and training in other disciplines. We conducted brainstorming sessions, made drawings, and constructed semantic maps, and we often invoked the expression "if…then." This manner of research is very similar to the design process itself. In this sense, we could say that design research has some unique characteristics when compared to other forms of research. Open, ill-structured, wicked, and non-linear are words we commonly use to describe the design process, and probably design research as well. This reality is not problematic – it is rather positive.

With this in mind, we believe that design research should be carried out with the same rigor that characterizes the hard sciences and the humanities. Here, we have suggested a small set of criteria that can be used to better construct a design theory. We do not propose a new general design theory – one of the points of contention among group members. While some believed it possible to construct a Universal Design Theory, others believed that it is not necessarily a useful focus for design research. For them, design research can achieve more than a superficial connection to practice by orienting itself toward the development of theories that are more directly applicable to specific and situational cases. In the end, the proposal of this essay was foundational – the formulation of some criteria characterizing a theory of design. We hope this discussion will continue and new criteria will be suggested, or that the criteria here be criticized and improved.