

The Role of Design Artifacts in Design Theory Construction

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As a discipline evolves, intellectual issues come into focus, and the outcomes of systematic inquiry grow in importance. The discipline of design is facing such a time, as scholars, researchers, and practitioners are devoting attention to creating categories for design practice and design research, articulating methods and processes, and, in some cases, building new design theories. The field of Human-Computer Interaction (HCI) is also experiencing an evolutionary broadening in scope that creates the need for design research. Many designers working in the HCI research community have expressed an increased interest in *research through design*, a research approach that employs methods and processes from design practice. However, without an agreed form of practice, evaluation, and outcome, it is hard to consistently develop design theory from research to design outcomes. In this paper, the authors begin to identify specific outcomes of research through design that form the basis for theory production. They present the research through design process and two different approaches of research through design (philosophical and grounded) that can lead to formation of design theory. They identify that extensible, systemic approaches to research through design are the most promising ones for developing design theory, and illustrate with examples.

Keywords: interaction design, research through design, HCI, theory, design theory

INTRODUCTION

As a discipline evolves, intellectual issues come into focus, and the outcomes of systematic inquiry - the practice of research - grow in importance. The discipline of design is facing such a time, as scholars, researchers, and practitioners are devoting attention to creating categories for design practice and design research, articulating methods and processes, and, in some cases, building new design theories and new theories of design. Today we are possibly on the verge of a revolution in design research that can advance beyond current forms of design practice and current research on design methodology (Dorst, 2008). The

field of Human-Computer Interaction (HCI) is also experiencing an evolutionary broadening in scope that has created a growing need for design research. HCI brings together behavioral scientists, computer scientists, and designers, with the goal of extending the capabilities of people through interaction with and the application of computational technology. With the transition of computing technology from the office to many different social contexts in which people live, HCI has shifted its focus from a narrow view on usability - increasing the efficiency and effectiveness of task completion - to more broadly consider the human experience. This expanded scope has shifted the type of investigation from tame problems that can be more definitively evaluated to messy issues more associated with wicked problems (Schön, 1983; Rittel & Webber, 1973), and this has created the need for design thinking. In this time of transition, HCI becomes an important focal point for design research, because it represents a domain where scientific, engineering, and design inquiry must begin to fit together and advance each other.

While the types and examples of design research inside and outside of the HCI community are growing, one of the problems in design research today is the failure to develop theory out of the observation of design practice and analysis of designed artifacts (Friedman, 2003). Many design research contributions often fail to document theory designers can apply in research and practice. This paper is an initial attempt to address this situation. Our goal is to advance the practice of design research by beginning to identify specific outcomes that form the basis for theory production. We have identified a particular type of design research that we call *research through design* to be quite promising in terms of building design theory that will increase the impact on both the HCI research community and on the design research community.

In this paper, we begin to identify specific outcomes of research through design that form the basis for theory production. We present the research through design process and two different approaches of research through design (philosophical and grounded) that can lead to formation of design theory. We identify that

extensible, systemic approaches to research through design are the most promising ones for developing design theory, and illustrate with examples.

RESEARCH THROUGH DESIGN IN HCI

Many designers working in the HCI research community have increasingly demonstrated an interest in *research through design*, a research approach that employs methods and processes from design practice. In the practice of *research through design* within HCI, interaction designers explore new problem spaces, codifying understanding through the construction of artifacts. Instead of having the intention to produce a commercial product, design researchers focus on how the application of design practice methods to new types of problems can produce knowledge (for a more complete discussion of research through design in HCI, please see Zimmerman *et al.*, 2007). A research through design approach offers several benefits that compliment the scientific methods of inquiry that dominate current HCI research, including:

- Allows the HCI research community to address wicked problems in the field, creating an “ongoing dialogue on what a preferred state should be”. This dialogue is desperately needed as the community begins to address messy issues, such as the use of technology to help elders remain in their homes or the use of mobile devices to monitor people’s behavior throughout the day.
- Allows for development of solutions that consider relationships between multiple phenomena in the design space instead of trying to control many variables and focus on a single relationship. The focus on wholes keeps the research focus on the construction of the future, of what should and could be, instead of on developing an understanding of the present.
- Creates research outcomes that serve as design exemplars that aid in the translation of findings to the practice community. Because designers currently communicate through exemplars, casting the knowledge in an artifact helps with this transfer and allows practitioners to apply the patterns they see in the research artifacts as they begin to make things that address the same or a similar problematic situation.
- Addresses the need within the HCI community to explore how new technology can advance current and future products and services. This connects HCI to its underlying goal of improving the human condition through appropriate application of computational technology, and the research can allow design researchers to influence the research directions of tech developers.
- Allows behavioral researchers not only to focus on evaluating current technology, but also to investigate how future products and services

might affect people. This reduces the risks of making new technical systems that fail and increases the likelihood of discovering new opportunities for technology that adds value to people’s lives. End users will still discover unanticipated uses for new products (Redström, 2006), but this type of research reduces the risk of making things that are wildly inappropriate and that have a high likelihood of non-acceptance.

In research through design, researchers make *prototypes*, *products*, and *models* to codify their own understanding of a particular situation and to provide a concrete framing of the problem and a description of a proposed, preferred state (Zimmerman *et al.*, 2007). Designers focus on the creation of artifacts through a process of *disciplined imagination*, because artifacts they make both reveal and become embodiments of possible futures. Design researchers have particularly turned to this method to address emerging social situations triggered by technology and materials that are so new, they have not yet generated interaction conventions or social norms around their use (Davidoff *et al.*, 2007). By practicing research through design, design researchers can explore new materials and actively participate in intentionally constructing the future, in the form of *disciplined imagination*, instead of limiting their research to an analysis of the present and the past.

RESEARCH THROUGH DESIGN PROCESS

Design researchers follow a typical design process in a research-through-design approach, involving six interconnected phases (Table 1; see Zimmerman *et al.*, 2004 for more details on how the design process maps to opportunities for knowledge production). Designers move iteratively between phases, developing sketches, models, and prototypes along the way to producing an ultimate particular in the form of a *thing* that suggests a future state.

In looking at research through design examples from the HCI community, we observed many different motivations for the work; however, these can be categorized into two approaches we have labeled *philosophical* and *grounded*. In taking a *philosophical* approach, researchers begin with a specific philosophical stance that they wish to either investigate or embody through a process of making. Examples include the Drift table as an investigation and embodiment of *ludic interaction* (Gaver *et al.*, 2004); Fren’s camera interface as an example of *rich interaction*, and associated frameworks which encouraged interaction design to move past button-press interfaces (Djajadiningrat *et al.*, 2000; Djajadiningrat *et al.*, 2004; Frens, 2006); the Affecter window as an investigation of the need for *reenchantment* in experience design (Sengers *et al.*, 2008); and the Reverse Alarm Clock as an exemplar of *designing for the self*: making products that more explicitly participate in identity construction (Ozenc *et*

al., 2007). The intention a researcher brings can come from his/her personal observations and reflections on what a preferred state might be, or he/she can be motivated by a previously articulated theory that the researcher wishes to investigate through his/her attempt to operationalize.

Table 1. Phases of the design process commonly employed in research through design in HCI

Phase	Activity
Define	Select focus (intention/motivation)
Discover	Develop data collection plan Collect data
Synthesize	Synthesize data Create a model identifying all factors in the problem Extract findings Create conceptual models Define opportunities
Generate	Sketch try many framings Critique Prototype refine a framing Evaluate
Refine	Select framing Make form Describe behavior
Reflect	Reflect on intention/motivation Reflect on problem framing Reflect on preferred state Reflect on design process Reflect on solution after next

Source: After Zimmerman *et al.* (2004).

In taking a *grounded* approach, design researchers focus on real-world problems by making things that force both a concrete framing of the problem and an articulation of a specific, preferred state that is the intended outcome of situating the solution in a context of use. These problems might come from research literature; current or ongoing social discourse, such as the increasing number of elders of sustainability that have become increasingly important topics in design today; and/or they may emerge from the design researchers' own fieldwork. Examples of grounded research through design include the Hug (DiSalvo *et al.*, 2003) and the SenseChair (Forlizzi *et al.*, 2005), which were designed to help support elders to age in place, and Davidoff *et al.*'s work on support for busy, dual-income families (Davidoff *et al.*, 2006; Lee *et al.*, 2006; Davidoff *et al.*, 2007). The Hug and the SenseChair both emerged from fieldwork on elders and their relationships with products that identified many different opportunity areas where technology could bring value to their lives. The SenseChair in particular grew out of the observation that as elders begin to experience decline, their physical world grows smaller and they spend more time in their favorite chair, making this an appropriate focus for the design of support systems. The work on support systems for dual-income families came from fieldwork that revealed how busy

families want to gain control over their lives, not control over their digital possessions as is the focus of much smart home technical research today. Using a grounded approach, researchers move from fieldwork that details the messy complexity of the problematic situation to a process of ideation and iteration that forces them to codify their knowledge in a specific thing that has a specific, intentional outcome as a preferred state.

THEORY PRODUCTION AND DESIGN

In its simplest form, a theory can be thought of as a model that describes the structure, relationships, and influences between phenomena (Friedman, 2003). Theories can describe dynamic situations, articulate processes and actions, or serve as taxonomies that detail related elements and structures without addressing the actions or influence of one upon another.

In scientific disciplines, researchers develop theory from many repeated observations, attempting to produce a construct that allows others to orient themselves at a high level, but also to see the complexity of what is really happening. Theories grow as part of research discourse where researchers propose and also refute, refine, and extend the work of others. Theories also evolve when researchers unite and consolidate many small theories into a larger unifying whole. Theories can be nascent, setting up a research agenda for further refinement; intermediate, where constructs are well formed, yet need to be tested; and mature, where a theory is so well established that no new evidence is likely to alter the explanation (Edmundsen & MacManus, 2007; Wikipedia 2008).

One of the challenges a research-through-design approach takes when intended to develop theory is the mismatch between the goal of theory - a unifying whole - and the goal of design practice - creation of an *ultimate particular* (Stolterman, 2008). However, many approaches common to the scientific disciplines share similarities with a research-through-design approach - in particular, that they describe the development of concepts that define relationships between properties. Mautner defines theory as exploration of a subject matter through the development of propositions (Mautner, 1996). This approach to the development of theory can easily map to the practice in design of sketching, where each sketch functions as a quick hunch or proposition as to the problematic situation and the preferred state. Weick defines theory as *disciplined imagination* that proceeds like artificial selection, where the researcher "defines, conducts, and interprets imaginary experiments" (Weick 1989, p. 516). Weick's constructs map well to the natural process of sketching and prototyping in design, where sketches evolve from a grounded understanding of the problematic situation and systematically explore framings. This is in contrast with other notions of

design practice, such as the romantic characterization, where the designer is described as an inherent genius (Fallman, 2003).

These perspectives cast the construction of theory as a design process involving sketching, critiquing, and refinement into a unifying whole that specifically addresses how all the elements and properties relate. This fits well with research through design producing artifacts as embodiments of theory in that the process is fundamentally the same. The challenge for the design research community is to connect the outcomes of research through design (the creation of the particular) with the focus in theory development (the creation of the universal). To understand how this can happen, we must examine more carefully the intentions and outcomes of research through design.

In both grounded and philosophical approaches to research through design, design researchers make propositions of “*what could/should be*” through the construction of artifacts. The artifact functions as a specific instantiation of a model - a theory - linking the current state to the proposed, preferred state. The propositions lay a foundation for a *nascent theory of the near future* to emerge as guidance both for other researchers and for practitioners who will soon be asked to make these new kinds of products.

PRODUCING DESIGN THEORY FROM RESEARCH THROUGH DESIGN

The evolution of design research has helped to produce theory that can be readily applied to many types of design, including products, services, systems, processes, media, and information. In the research-through-design process, initial theories take the form of an artifact. In addition, a research-through-design approach has other valuable outcomes, including reflection on new perspectives, extensible constructs, and systematic approaches to design and design research, often in the form of processes and design/research methods.

Research through design outcomes that can form the basis of design theories can be distinguished in two important ways. The first is that they have *extensible constructs*. Most often, this takes the form of describing the relationships among groups of phenomena. For example, the Product Ecology is a design theory that takes a systems approach to articulating all of the elements of context that must be taken into consideration when designing a product. The constructs in the theory arose from a study of elders and products in the home, the research through design artifacts the Hug and the SenseChair, and further study on cleaning and caregiving in the home to test the initial constructs of the theory. The Product Ecology can be used in other contexts, and factors can be used singly or in combination to discover the space of opportunity for creating new products (Forlizzi, 2008).

Often, as outcomes of research through design move from the specific to the general, other types of design knowledge can be created in the form of new processes, design methods, and empirical evaluations. A proposition might take the form of how to apply new technology to a holistic solution. For example, the a-book relied on participatory design methods to forge a missing link between paper and digital material in the use of biology lab notebooks (MacKay *et al.*, 2002). Alternatively, it could be an articulation of what the preferred state could be. The Apple Knowledge Navigator video, created in 1987, showed a futuristic vision of an intelligent desktop agent that assisted a university professor (see Spool, 2007 for a description and the video). The technology was not yet available to realize the functions portrayed in the video, but this video artifact started a tradition of using video to envision what designed future states might be. Ultimately, outcomes can also be the application of design in a new domain, including economics, the study of organizations, biomedicine, service applications, and others.

THE FUTURE OF DESIGN THEORY IN HCI

In order to make design theory useful within the field of HCI, the community needs to understand theory in way that is useful. For an interdisciplinary community, this suggests a level of extensibility and verifiability that will allow researchers to articulate a contribution in their own research, and allow non-designers to become familiarized with the methods and approaches of design. This could be done in several ways. Research programs could begin to focus on research through design, nurturing multidisciplinary and cross-disciplinary insights into design and HCI, creating a body of examples for the community to build on. The construction of design theory could be stressed as “disciplined imagination”. Criteria could be developed for evaluating design theory contributions in HCI. Finally, new design processes, practices, and methods could be developed that will advance design theory within HCI.

CONCLUSION

The field of Human-Computer Interaction (HCI) is experiencing an evolutionary broadening in scope that has created a growing need for design research. Many designers working in the HCI research community have expressed an increased interest in *research through design*, a research approach that employs methods and processes from design practice. Others have articulated the need to develop and situate design theory as an important outcome of HCI research. In this paper, we have attempted to address this situation by defining design theory, and illustrating where the seeds of theory evolve from research-through-design efforts.

We hope that in taking this initial step towards defining design theory for the HCI and interaction design communities, we can begin a serious discussion of what design theory is and what role it plays in HCI research. We will continue to refine and evaluate our ideas with others in the HCI and interaction design communities. Our goal is to better support the integration of research through design in the discipline of HCI.

REFERENCES

- Davidoff, S., Dey, A., & Zimmerman, J.** (2007). Rapidly exploring application design through speed dating. In *Proceedings of UbiComp* (pp. 429-446). New York: Springer.
- Davidoff, S., Lee, M.K., Zimmerman, J., & Dey, A.** (2006). Principles of smart home control. *Proceedings of UbiComp* (pp. 19-34). New York: Springer.
- DiSalvo, C., Gemperle, F., Forlizzi, J., & Montgomery, E.** (2003). The Hug: An exploration of robotic form for intimate communication. In *Proceedings of RO-MAN* (pp. 403-410). New York: IEEE.
- Djajadiningrat, J. P., Gaver, W. W., & Fres, J. W.** (2000). Interaction relabelling and extreme characters: Methods for exploring aesthetic interactions. In *Proceedings of the Conference on Designing Interactive Systems* (pp. 66-71). New York: ACM Press.
- Djajadiningrat, P.J., Wensveen, S.A.G., Frens, J., & Overbeeke, C.J.** (2004). Tangible products: Redressing the balance between appearance and action. *Personal and Ubiquitous Computing*, 8, 294-309.
- Dorst, K.** (2008). Design research: a revolution-waiting-to-happen. *Design Studies*, 29, 4-11.
- Edmondson, A.C., & McManus, S.E.** (2007). Methodological fit in management field research. *Academy of Management Review* (in press).
- Fallman, D.** (2003). Design-oriented human-computer interaction. In *Proceedings of the Conference on Human Factors in Computing Systems* (pp. 225-232). New York: ACM Press.
- Forlizzi, J.** (2008). The product ecology: Understanding social product use and supporting design culture. *International Journal of Design*, 2(1), 11-20.
- Forlizzi, J., DiSalvo, C., Zimmerman, J., Mutlu, B., & Hurst, A.** (2005). The SenseChair: The lounge chair as an intelligent assistive device for elders. In *Proceedings of the Conference on Designing for User eXperience*. New York: ACM Press.
- Frens, J.** (2006). A rich user interface for a digital camera. *Personal and Ubiquitous Computing*, 10(2-3), 177-180.
- Friedman, K.** (2003). Theory construction in design research: Criteria, approaches, and methods. *Design Studies*, 24, 507-522.
- Gaver, W. W., Bowers, J., Boucher, A., Gellerson, H., Pennington, S., Schmidt, A., Steed, A., Villars, N., & Walker, B.** (2004). The drift table: Designing for ludic engagement. In *Extended Abstracts of the Conference on Human Factors in Computing Systems* (pp. 885-900). New York: ACM Press.
- Lee, M.K., Davidoff, S., Zimmerman, J., & Dey, A.** (2006). Smart homes, families, and control. In *Proceedings of Design and Emotion*. Delft: Design and Emotion Society.
- MacKay, W., Pothier, G., Letondal, C., Bøegh, K., & Sørensen, H. E.** (2002). The missing link: augmenting biology laboratory notebooks. In *Proceedings of the Symposium on User Interface Software Technology* (pp. 41-50). New York: ACM Press.
- Mautner, T.A.** (1996). *Dictionary of philosophy*. Oxford, UK: Blackwell.
- Nelson, H. G., & Stolterman, E.** (2003). *The design way*. Englewood Cliffs, NJ: Educational Technology Publications.
- Ozenc, K., Brommer, J. P., Jeong, B., Shih, N., Au, K., & Zimmerman, J.** (2007). Reverse alarm clock: A research through design example of designing for the self. In *Proceedings of the Conference on Designing Pleasurable Products and Interfaces* (pp. 392-406). New York: ACM Press.
- Redström, J.** (2006). Towards user design? On the shift from object to user as the subject of design. *Design Studies*, 27(2), 123-139.
- Rittel, H. W. J., & Webber, M. M.** (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155-169.
- Schön, D.** (1983). *The reflective practitioner*. London: Temple Smith.
- Sengers, P., Boehner, K., Mateas, M., & Gay, G.** (2008). *The disenchantment of affect*. Personal and Ubiquitous Computing, 12(5), 1-12.
- Spool, J.** (2007). Knowledge Navigator deconstructed: Building an envisionment. Retrieved March 2008, from http://www.uie.com/articles/knowledge_navigator/
- Stolterman, S.** (2008). The nature of design practice and implications for interaction design research. *International Journal of Design*, 2(1), 55-65.
- Weick, K. E.** (1989). Theory construction as disciplined imagination. *Academy of Management Review*, 14(4): 516-531.
- Wikipedia** (2008). Retrieved March 2008 from <http://en.wikipedia.org/wiki/Theory>
- Zimmerman, J., Evenson, S., & Forlizzi, J.** (2004). Discovering knowledge in the design case. In *Proceedings of FutureGround*. Design Research Society.
- Zimmerman, J., Forlizzi, J., & Evenson, S.** (2007). Research through design as a method for interaction design research in HCI. In *Proceedings of the Conference on Human Factors in Computing Systems* (pp. 493-502). New York: ACM Press.

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Published online 28 November, 2008
ISSN 1749-3463 print/ ISSN 1749-3471
DOI: 10.1080/17493460802276893
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